COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

January, 1942

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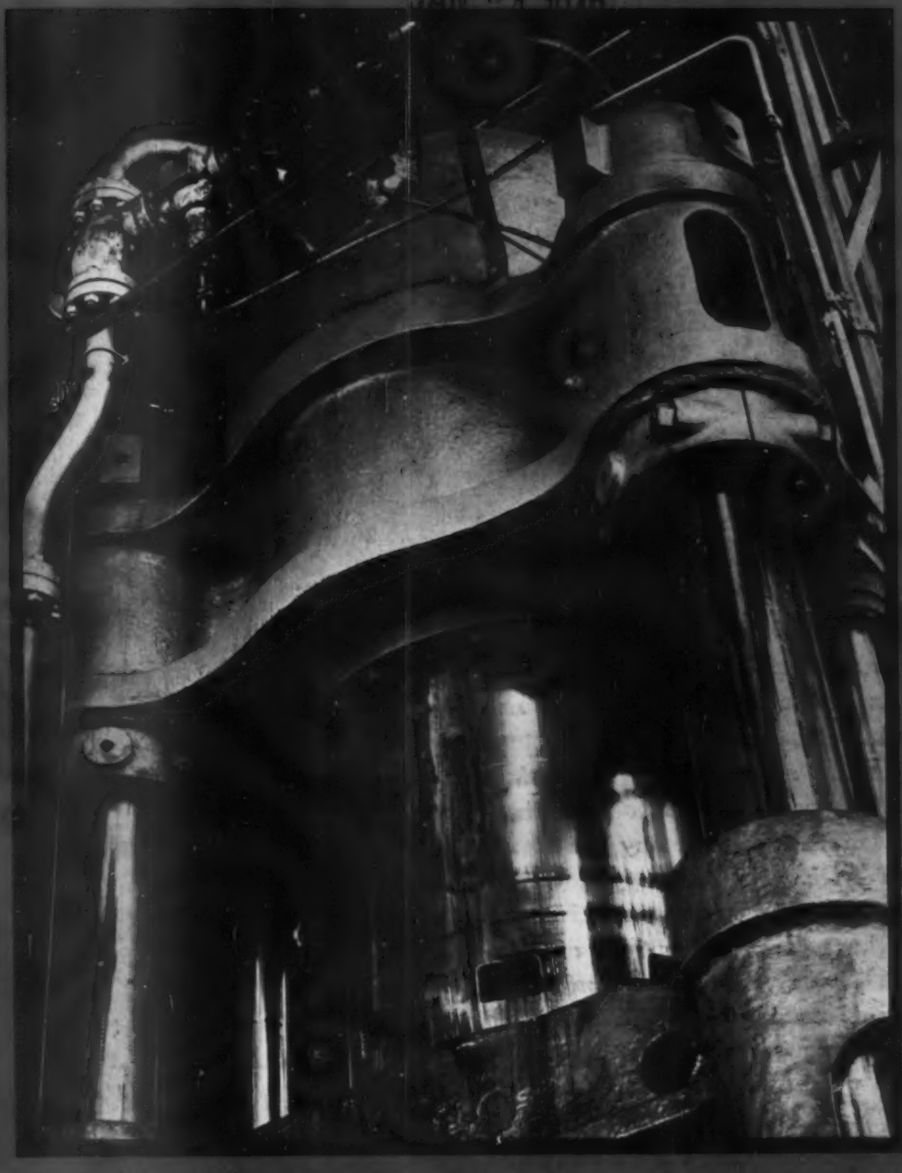

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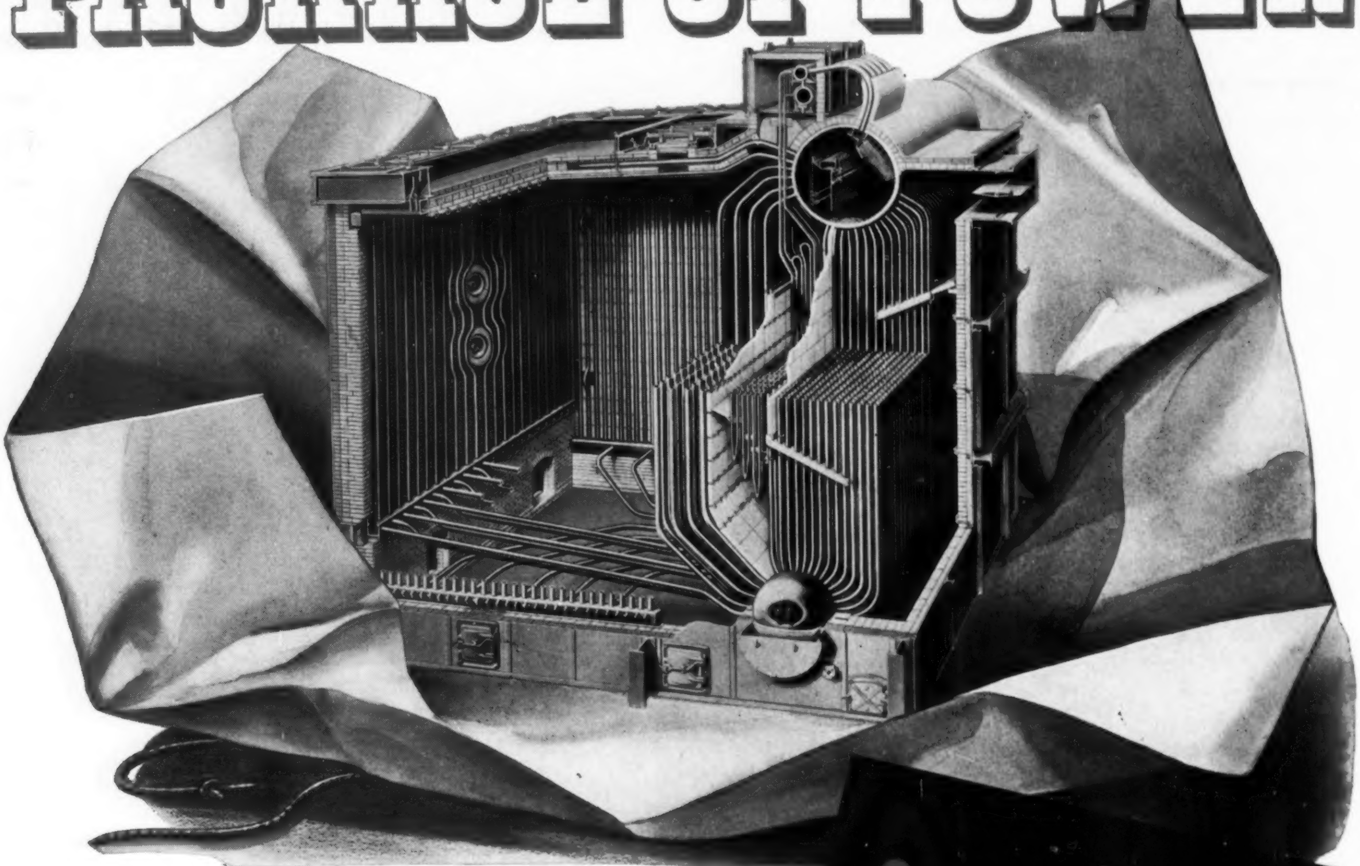

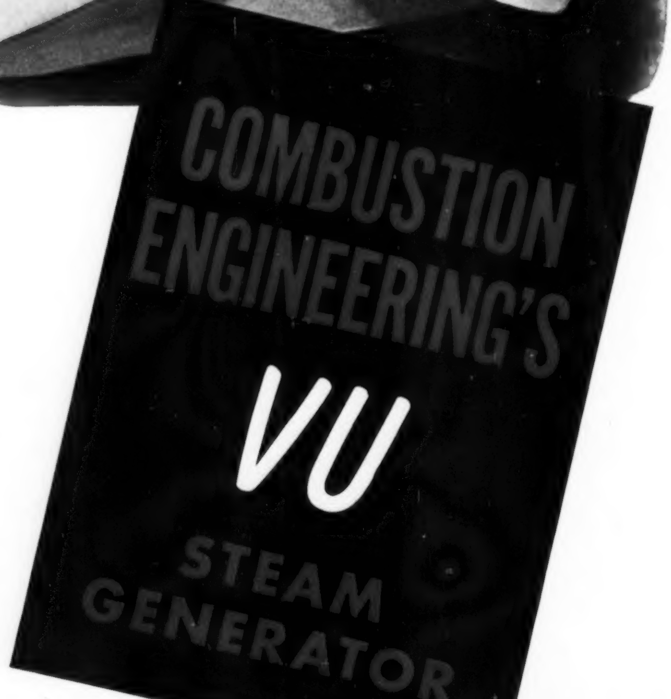

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COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

VOLUME THIRTEEN NUMBER SEVEN

CONTENTS

FOR JANUARY 1942

FEATURE ARTICLES

EDITORIALS

DEPARTMENTS

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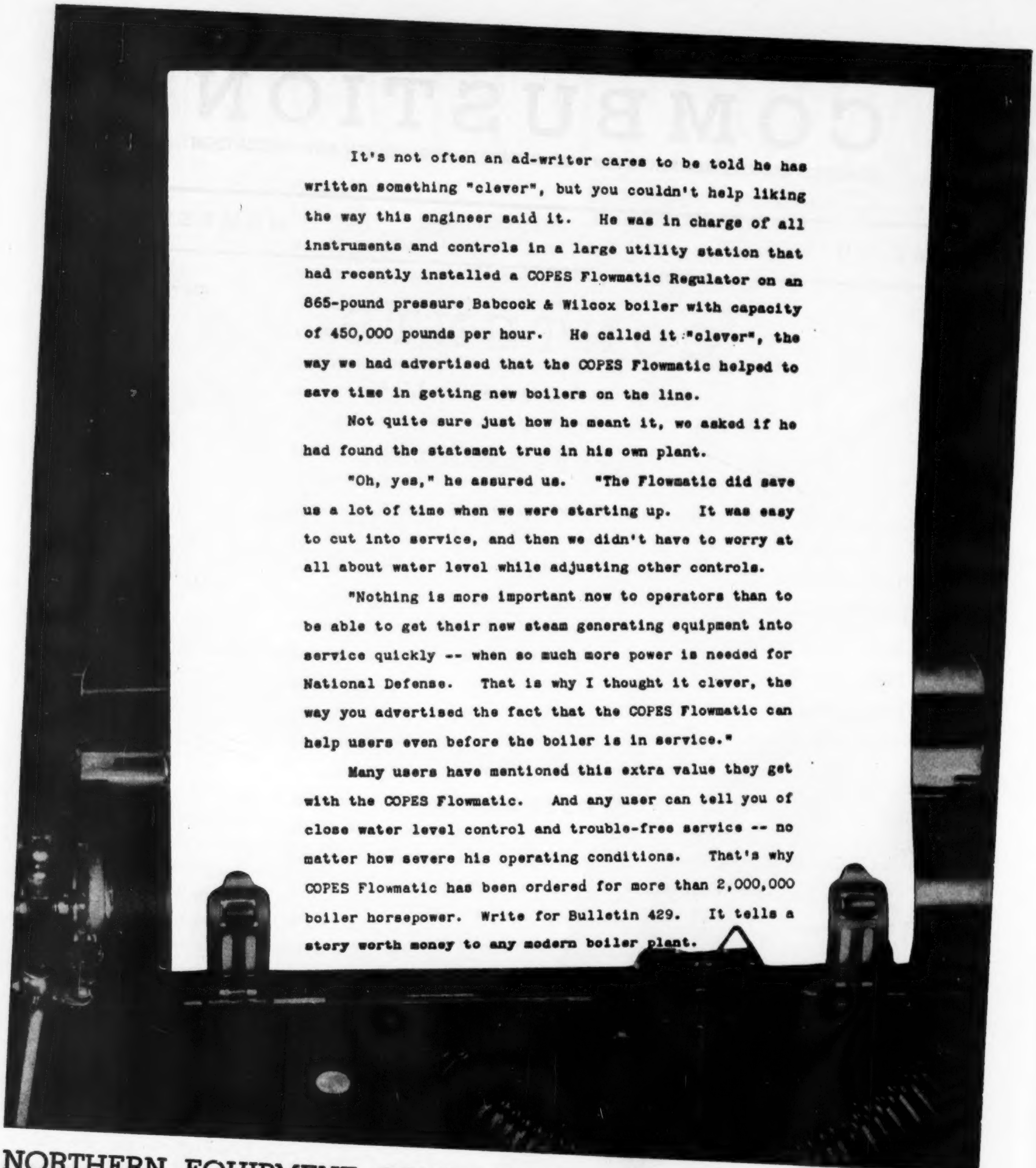

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EDITORIAL

A Challenge

For several years past COMBUSTION has been privileged, in its January issue, to report the performance of Port Washington Station for the preceding twelve months. Each successive year has shown consistent improvement, with an average station heat rate of 10,580 Btu per net kilowatt-hour output for 1941, a monthly low of 10,395 Btu and availability of 96.6 per cent for the year.

The long-held record of this station now appears to have been challenged by recently announced figures of 9200 Btu per net kilowatt-hour for the mercury-steam installation at Kearny and 10,189 Btu for 168 accumulative hours at the 2500-lb pressure, 940-F extension to Twin Branch. The latter may be considered as still in its initial stage of operation, hence its 72.5 per cent availability for six months' operation is inconclusive.

Obviously, the cycle efficiency with the steam conditions at Twin Branch is higher than that at Port Washington which operates at 1325 lb pressure and 825 F total steam temperature. Yet, despite the fact that the latter has now been in operation for more than six years, during which many changes in practice have taken place, its conservative and satisfactory design for *overall* economy has been such that the second section of the plant, now on order, will be practically a duplicate.

Meeting the Power Demand

According to figures released by the Edison Electric Institute, the energy sold by private electric utilities to ultimate consumers during 1941 reached an all-time high of over 140 billion kilowatt-hours. This represented an increase of 18.3 per cent over that sold during 1940. As would be expected, the greatest increase was in sales to large commercial and industrial establishments, but the rural load and residential consumption showed surprisingly large gains, which reflected a record year in the sale of electrical appliances.

Generating capacity added by the private utilities during the year was close to two million kilowatts. This figure, however, fell short by some six hundred thousand kilowatts of the total that had been scheduled to go into operation—due partly to the turbine situation and partly to labor troubles. As a result some rescheduling for 1942 and 1943 became necessary.

Peak demands increased faster than the capacity added and this drew to some extent on the reserves which, nevertheless, are still nine million kilowatts in excess of the sum of individual peaks for the industry as a whole. This phase of the situation, as pertains to individual systems, is being assisted by further interconnections and in several cases by the transfer of equipment either on order or in reserve.

Now that we are actually in the war, "all-out" production on a scale as envisioned in the President's recent message will entail power demands far beyond those previously anticipated. Moreover, expanded requirements of the armed services are likely to impede further the deliveries of materials needed for power equipment.

However, the situation is not likely to become as acute as some would infer. Compensating factors are to be found in the large reduction in load incident to the enforced curtailment or discontinuance of much non-essential production, the pending adoption of nationwide daylight saving, longer working hours and more general employment of the three-shift plan which will tend not only to make greater use of present installed capacity but also should prevent a sharp rise in peak demands.

Finally, the American people are only just beginning to experience wartime restrictions, and when these are fully in effect a willing response to curtailment in domestic and small commercial loads will be forthcoming if the necessity should arise. These combined account for more than a third of the total central station load for the country as a whole. Rationing of electricity became necessary and was successfully carried out in the South last Fall. If occasion arises it can be applied elsewhere.

Until such expedients have been exhausted there would appear to be no occasion for alarm over the power situation; although every effort will be made to improve it, consistent with the fulfilment of pressing war demands.

Deferments

Extension of the military age to forty-four and the announced intention to reclassify many who had previously been accorded a deferred status is likely to affect some organizations engaged directly or indirectly in power plant work.

Although it is probable that engineers whose work is contributing to the war effort will continue to receive special consideration, one must not lose sight of the fact that a much larger percentage of industry is now engaged in war production than was the case when the draft was first initiated, and that this percentage will continue to increase. Hence there will be fewer non-essential industries which will contribute to the greatly expanded requirements of men for the armed services. This may make it more difficult for firms to secure deferment for men within the military age unless it can be proved that they are both indispensable to war work and cannot be replaced by others not subject to military service.

Although, thus far, most firms having legitimate reasons for requesting deferment in individual cases have been generally successful in their efforts, it is uncertain as to how long this may continue. Therefore, it might be well for managements to re-survey their personnel with a view to the potential shifting of duties and responsibilities such as would least interfere with the orderly progress of work, if the necessity arises.

Correct Power Station Lubrication Not Based on "Rules of Thumb"

By HOWARD COOPER
Chief Lubricating Engineer,
Sinclair Refining Company

A review of the principles underlying the lubrication of power plant equipment and the various conditions that must be investigated by the lubrication engineer before prescribing the correct oil for the individual case.

JUST as a doctor diagnoses a patient's condition before prescribing a remedy, so a lubrication engineer analyzes the mechanical and operating conditions in a power station before making recommendations of lubricants. To a medical man each case is individual and different and calls for examination into all contributing influences and the physical character of the patient. Likewise, to a lubrication engineer every installation is a special case, differing in mechanical and operating aspects from all others and, therefore, demanding individual consideration. No definite inviolable rules can be followed in prescribing lubricants; correct lubricant recommendations will vary to suit the combination of prevailing conditions.

Primary interest quite naturally centers around the major units, the prime movers. A complete study goes back as far as the boiler house and water supply, and influences affecting lubrication may start with the character of the boiler water.

Since a lubrication engineer cannot be guided by set rules, what factors are included in his analysis?

Steam Engine Lubrication

First, consider an installation where reciprocating steam engines are the prime movers. Analysis will start at the engine, its design, speed, load, frequency and duration of peak demands, stages of expansion, closeness of fit or condition of wear, accuracy of alignment, provisions for lubrication, oil recovery or filtration system, etc. With specific attention to the steam cylinders, influences from the steam must be examined—pressure, temperature, superheat, moisture content, recovery and use of condensate. This leads to investigation of factors affecting the quality of the steam, such as size and length of steam lines, bends and pockets, piping insulation, drafts, separators, boiler capacity, water treatment and boiler foaming. Then, on the exhaust side, the disposition of the steam or condensate is important, especially where condensate is used for recirculation through the boilers or for plant processes. Such consideration directs attention to location and effectiveness of exhaust separators, purity of the condensate, etc.

Obviously, with such an array of factors to be recognized, no sensible lubricant recommendation can be made by rule of thumb. Furthermore, besides an understanding of the operating conditions, the lubrication engineer must have a knowledge of the capacity and capability of the lubricants available, and the performance to be expected from them in the face of individual conditions and the composite of all conditions. Naturally, of great assistance and guidance is the past record of performance of lubricants on the installation under study, as well as experience in other power stations.

Yet, complex as the above outline may seem, the line of thinking that directs the lubrication engineer's recommendations is not confusing. His major problem, after ferreting out all the contributing factors, is to evaluate the importance of each and its influence on the composite of all conditions.

Continuing attention to the lubrication of the steam cylinders, there are certain fundamental principles on which a recommendation of steam cylinder oil is based. These principles must be accepted in a broad sense, and not confined by specific limiting figures or values.

Definitely first is that atomization of the oil in the steam is vital to effective lubrication of the valves and cylinders. The efficacy of the spoon or quill which introduces the oil to the center of the steam line is important. The longer the travel between point of introduction of the oil into the steam and the cylinder, the greater is the opportunity for complete atomization. Oil, of course, should never be fed ahead of the separator.

As regards atomization, the higher the temperature of the steam and the greater the opportunity for atomization, the higher the viscosity of the oil that may be successfully used. Also to be recognized is the fact that dark steam refined cylinder oils will atomize less readily than bright or filtered stocks; yet dark oils have better adhering properties.

Steam temperature, a function of pressure and superheat, suggests certain selection of oil when considered alone. Obviously, the higher the pressure, and thereby the temperature, the higher the viscosity of the oil that may be used, and which may be best suited because of the influence of temperature in reducing viscosity.

Moisture content in the steam, however, cannot be overlooked; and it must be remembered that expansion is a cooling process, so that steam which enters the cylinder dry and superheated will develop moisture content during expansion. Mineral oil will not adhere to or spread a continuous film on wet surfaces; therefore, fatty oil must be added to the mineral oil to permit it to

provide unbroken lubrication on the surfaces of cylinders and valves. The higher the moisture content the greater the percentage of saponifying or emulsifying agent that is needed.

The fatty oil or saponifying agent cannot be completely separated from the oil, and its presence in boiler water or in condensate may rule against the use of or control the acceptable amount of compounding. Reducing or eliminating the compound imposes greater responsibility on atomization, which may have to be made more effective through lower viscosity oil; and for adequate lubrication higher consumption of oil may in some cases be required.

It will be seen that the correct recommendation will be a compromise. The lubricant cannot be chosen for any one condition, but must be one that will most effectively and efficiently satisfy the composite requirements imposed by all conditions considered together. Lower viscosity than that suited for high steam temperature may have to be accepted because of inadequacy of opportunity for proper atomization; lower percentage of compound than demanded by the moisture content of the steam may have to be adopted because of after use of the exhaust condensate; the better adhering properties of dark steam refined oil may have to be sacrificed in the interest of improving atomization; low oil consumption may have to be waived in favor of more effective lubrication. The lubrication engineer must evaluate all the factors in selecting an oil which will best satisfy the composite of all the conditions.

Lubricating the Auxiliaries

The mistake should not be made that the choosing of the lubricant for the main units has solved all the steam cylinder problems in the plant. Conditions under which auxiliaries and pumps operate may be different as to steam pressure and temperature, moisture content, disposition of the steam, mechanical design and method of lubrication. The best oil for the main units may not and often is not the right oil for other steam cylinder service in the plant.

The problem of lubrication of the bearings and other parts of the main engines does not involve as complex a study, and investigation is confined entirely to the engine itself—its speed and loads, clearances and the lubricating system. If the parts are lubricated by drip cups, and the oil is not recovered for re-use, the objective is to select the lubricant which will permit maintenance of the best bearing temperatures and the lowest frictional loss with minimum consumption. More likely, however, the method of lubrication will be through some sort of a recirculating system. Such installations call for a study of the system, provisions for settling or removing water and other contamination, filtration and ultimate use of oil after removal from the system.

Fundamental principles also guide the lubrication engineer in recommendations for this service. The higher the speed and the closer the clearance, the lower the viscosity of the oil that may be used; low speed and heavy weight load suggest heavier viscosity. High rate of flow of oil over the bearings permits consideration of lower viscosity than weighted load or low speed might otherwise suggest. Continuous recirculation demands stability quality in the oil; this is not required by a once-through method of lubrication. Small settling tank capacity demands ability for quick separation, and high demulsibility characteristics in the oil. For lubrication by the once-through method so-called red engine oil is the most efficient and economical. Re-circulation systems call for more highly refined oils, with capacity for long life over long periods of time.

The bearing oil for the main engines may in some instances be used also for bearings on auxiliary equipment. On the other hand, the lubricating systems on auxiliaries may not permit economy of use, and a different oil may be more practical and economical; furthermore, the viscosity requirements of auxiliaries may be different from those of the main engines. This consideration must be recognized where it is the practice to use oil recovered after use on the main engines for bearings of auxiliaries. Some auxiliaries may be designed with self-contained crankcase circulating systems, for which efficient lubrication can be assured only through an oil suited to the particular conditions imposed. As with other recirculating systems, for long life and for quick and effective separation of moisture and contaminants, viscosity, demulsibility, stability and generally extra refinement are "must" considerations. Opportunity for dissipation of heat, especially in closed crankcases, and the influence of conducted heat or high surrounding temperatures should not be overlooked. Increased temperature reduces oil viscosity, and viscosity and the lubrication protection afforded by viscosity must be considered in connection with temperatures of operation. Mechanical design alone, then, is not a sufficient guide for the selection of the lubricant; it is but one factor to be considered in conjunction with other operating conditions.

Air Compressor Lubrication Involves Oxidation Problem

The air compressor cylinder presents a still different problem. In the steam cylinder the oil is not subject to any oxidizing effect, since in use it is exposed to an atmosphere of steam. Oil on the cylinders and valves of an air compressor, however, is exposed to air at high temperature and these conditions accelerate oxidation with resultant carbon deposit and sludge deposition.

A primary principle for lubrication of air compressor cylinders is to maintain rate of feed at the lowest possible minimum, consistent with effective lubrication. The conditions within the compressor cylinder, as mentioned above, call for oil of high degree of refinement, distinctly good stability and resistance to carbon and sludge formation. High viscosity oils are not generally used in air compressor cylinders, although when compressing to high pressures higher viscosity oils are used, not alone because of temperature influence on viscosity, but for the benefit of the greater stability which is characteristic of high viscosity oils. In multi-stage compressors best results may be obtained through different oils in the various stages.

Electric motors seldom offer complexities as regards lubrication. Ring oiling is a widely used method. Selection of the proper type and body of oil to suit the speed, temperature and load characteristics is relatively simple. Some larger motors may require heavier oils than smaller sizes, due to lower speed, weight of armature and magnitude or character of load forces; but there is a continuous flow of oil over the bearing and light oil will permit freer ring travel and also will carry

away heat more effectively. An important point is to recognize the ring-oiled bearing as a small capacity circulating system; therefore, for long-time service without oil depreciation, well refined and highly stable oils are certain to provide the most in efficiency and economy of use.

Greases

Grease lubrication is a big subject. Suffice it to mention in connection with electric motors and other equipment which may be provided with ball bearings that soda soap greases are the accepted type of greases for anti-friction bearings. Bearing manufacturers regard smooth soda greases—as distinct from the more common calcium soap cup greases—as essential to long service of anti-friction bearings. The grease should be made with the best suited basic oil and correct consistency for the service. Cup greases, or calcium greases, are adapted to plain bearings and where application is through grease cups or pressure fittings.

Steam Turbine Lubrication Presents a Different Set of Conditions

But what if the prime mover is a turbine? Naturally, the analysis does not follow the same course of study necessary for the selection of steam cylinder oil. The lubrication conditions involve high speed, and continuous recirculation of the oil at elevated temperatures. The importance of uninterrupted operation and recognition of precision character of turbine construction command that careful attention be given to its lubrication—for lubrication must not fail if continuous service is to be maintained.

First to be understood is that the oil does two important things: it lubricates the bearings, and it carries away the heat generated there. Clearances are close and speed is high. A light viscosity oil is needed to fit the close clearances and speed and to absorb quickly the heat that must be carried away and dissipated. The bearings are supplied with a flooding stream of oil, which is continuously recirculated from a self-contained lubricating system. Heat of the steam contributes to the oil temperature by conduction; and moisture unavoidably bleeds into the system, which embraces settling and cooling tanks as important features. The oil, then, besides having a correct viscosity must resist the effects of the imposed temperature without permitting excessive sludging over long periods of use; that is, it must be stable against depreciation by oxidation. The acidity value should not rise abnormally, nor the viscosity suffer rapid increase. At the same time, the oil must free itself quickly from water and from entrained air in the settling compartments, and give up the heat carried from the bearings. Therefore, the oil must be highly demulsible; an emulsion of oil and water with entrained air impairs the efficiency of lubrication, possibly to the point of failure.

Recent studies, particularly with respect to geared installations, have given much attention to rusting effects that have appeared as pitting on the faces of precision cut gear teeth and other vital surfaces. In new turbines especially is this aspect important. Turbine oils are specially refined to give long life stability, high demulsibility, and also may contain rust inhibiting additives.

As has been pointed out, a correct lubricant recommendation is not a hit-or-miss suggestion. It is based on an understanding of the mechanical and operating conditions and contributing influences plus a knowledge of the capability of oils under those conditions, and is further supported by sound principles of reasoning and a background of experience. A cheap, poorly refined oil may be inefficient and a poor investment; but, likewise, a highly refined and costly oil may not be the most economical under some circumstances. The value of an oil for a specific set of operating requirements cannot be judged by its price; a sincere lubrication engineer seeks for efficiency and economy, and his thinking is not influenced by price per gallon, but rather by cost per unit of output, which includes maintenance.

Turbine Trends

An all-time record has been established by the number and aggregate capacity of steam turbines ordered during the past year. One company alone reports $2^1/_2$ million kilowatts of turbine-generators on order for public utilities and industrials and over nine million horsepower for the Navy, in addition to many propulsion units for the merchant marine.

While the maximum size of turbine-generators, as established some years ago, has not been exceeded, there has been a marked increase in the number of units of large capacity for utility service. In the upper size range Westinghouse reports three 150,000-kw cross-compound units and one of like capacity in the two-cylinder tandem type; also a 100,000-kw high-pressure machine and an 80,000-kw single-cylinder low-pressure unit. General Electric lists eleven single-cylinder units ranging from 50,000 to 80,000 kw at 1800 rpm and five 85,000-kw cross-compound sets with the high-pressure elements running at 3600 rpm and the low-pressure at 1800 rpm. Of fifty-six large turbine-generators on order or under construction by this company for utility service the average capacity is 41,600 kw and forty of these machines, representing about half the total capacity, operate at 3600 rpm. In the 25,000 to 60,000-kw range twenty of the units are of the tandem-compound type.

Of the fifty-six machines mentioned, ten are designed to operate at 1200 to 1350 lb per sq in.; twenty-five at 800 to 875 lb; twelve at 600 to 650 lb; eight at 300 to 450 lb; and one at 195 lb. Six will use steam at 925 to 950 F; thirty at 900 F; eleven at 800 to 850 F; and nine at 650 to 750 F. With one exception all the 3600-rpm units of 25,000 kw and above have hydrogen cooling of the generators, as have also three 80,000-kw, 1800-rpm generators. The highest pressure turbine-generator installed during 1941 was a G. E. cross-compound unit taking steam at 2300 lb and 940 F. Another high-pressure machine of 25,000 kw capacity is nearing completion for topping service to operate at 1825 lb pressure and an initial steam temperature of 960 F.

Although complete standardization in design appears impracticable for turbine-generators, it is noticeable that few changes have been made in basic construction, and the turbine manufacturers by developing a family of designs for the complete range of sizes, have been enabled better to cope with the unprecedented demand of the past eighteen months.

Recirculation of Fly Ash in Boiler Furnaces

From the standpoint of making for poorer furnace conditions and increased loading of the gases discharged from the stack, the author concludes that recirculation of fly ash is seldom, if ever, desirable with pulverized-coal installations. Moreover, he points out that with proper design of furnace and burners to provide adequate turbulence and with proper operation the need for such recirculation disappears. With stokers, however, there may be conditions where the recirculation of cinders is justified.

By HUDSON H. BUBAR

THERE have been numerous attempts to burn, by recirculation in the furnace, the carbon content of the fly ash escaping the boilers on both pulverized-coal and stoker-fired installations. The possible benefits derived from such practice appear questionable on those installations with which the writer has come in contact. Due to the broadly varying conditions of application and operation encountered, each application must be individually analyzed before definite conclusions can be drawn.

The most common procedure with recirculation is to return the fly ash directly from the collector to the furnace by means of an air jet. Another procedure is to mix the fly ash with the coal going either to the pulverizers or to the stokers, as the case may be.

As the conditions attendant to pulverized-coal applications are so different from those met with in stoker-fired installations it is advisable that they be discussed separately. Therefore, in order to differentiate between the two, the term "fly ash" will be applied to pulverized-coal installations and "cinders" to stoker-fired installations.

Pulverized-Coal Applications

Successful combustion is largely dependent upon adequate pulverization of the coal, proper mixture of the pulverized coal with the air and proper furnace temperatures. Other factors such as the moisture content, the Btu value, the percentage of ash, the percentage of volatile and the sulphur content of the coal also have bearing on the efficiency of the installation.

To obtain proper combustion it is necessary that each coal particle projected into the furnace be in direct contact with sufficient oxygen to accomplish complete combustion. This is generally effected through high furnace turbulence, resulting in a thorough mixture of the entering air and coal. As the problem develops, other points arise either directly or indirectly effecting the success of the operation. For example, in order to obtain complete combustion of a high-ash coal the percentage of excess air must necessarily be higher than in the case of a low-ash coal. The ash particle may be in direct contact with a coal particle, thereby retarding combustion or, the ash particle may be isolated in its own nucleus of oxygen, thereby occupying the space of a coal particle and adding to the excess air required.

Obviously, the ratio of ash to combustible is much higher in fly ash than in the coal. Where the combustible content of the coal will vary roughly between 75 and 96 per cent that in the fly ash will vary between 7 and 75 per cent, with an approximate average of 40 per cent. Also, the volatile matter in the fly ash is very low. The combustible content may, therefore, be considered as carbon, most of which is in the form of coke. Coke requires higher ignition temperatures than does bituminous coal. It therefore follows that, in order to successfully burn this coke, higher furnace temperatures are required. Also, this coke is diluted with a high percentage of ash, and to offset this dilution increased air is required. Under these conditions a considerable portion of the ash is vitrified. This increases erosion all along the line.

The widely varying carbon content of fly ash may result from any one or more of the following causes:

1. The type of coal burned—high or low volatile, percentage of ash, sulphur, etc.
2. The fineness to which the coal is pulverized.
3. The percentage of excess air supplied to the furnace.
4. The degree to which the air and coal are mixed.

Naturally, in different parts of the country, there exists a wide variation in the type of coal burned. It may have an ash content ranging anywhere between 4 and 25 per cent. There is also a wide range in the percentage of volatile, a varying percentage of sulphur, etc. The ash also will vary in its characteristics, with a fairly broad range in the silica, alumina or iron content. All of these conditions influence combustion, and all of them have a decided bearing on the percentage of carbon escaping the boiler unless proper means of control are established.

Lack of proper turbulence in the furnace may result in a high carbon loss. Where the pulverized coal is not thoroughly and properly mixed with the incoming air, or where blanketing effects occur, incomplete combustion is bound to follow.

All furnaces and burners should be designed and installed to obtain the best possible combustion conditons, but in introducing fly ash by recirculation this important factor is often ignored with the result that proper burner

operation is decidedly retarded. Attempts to obtain too high a CO_2, by reducing the excess air, very often defeat the intended purpose and result in reduced boiler efficiency and increased carbon loss.

This boils down to the plain fact that with proper burners and proper burner operation there should be no excessive carbon loss and consequently no reason for recirculation of the fly ash.

Where the ash content of the coal is low, say below 6 per cent, and where the carbon content of the fly ash escaping the boiler is above 50 per cent, there might be a possibility of increased efficiency. However, where the ash content of the coal is above 12 per cent or where the percentage of carbon in the escaping fly ash is below 40 per cent, it does not appear possible to show any saving through recirculation of the fly ash. These statements are based on the following conditions, as observed:

Recirculation multiplies the percentage of ash passed through the boiler. The extent of this build-up is dependent, to a great extent, upon the efficiency of the fly-ash collectors and to a lesser extent upon the general furnace and boiler construction.

The original percentage of ash in the coal may be taken into consideration only in so far as it establishes the original furnace conditions. In all cases where a high-ash coal is burned, the total percentage of fly ash recirculated is greater than where a low-ash coal is burned. But based on the original percentage of ash in the coal, the increased fly-ash loading in the furnace appears to be in direct ratio to the collector efficiency.

Fly-Ash Loading of Gases Increased

In those cases observed it was indicated that recirculation increased the fly-ash loading of the gases entering the collector to a point where the total amount of fly ash escaping from the collector approximated the original amount of ash in the coal burned; i.e., where a coal having a 6 per cent ash is burned and where, on installations in which no recirculation occurs, this gives an approximate fly-ash loading of one grain per cubic foot of gas; then recirculation of the fly ash through the collector and the boiler furnace builds up to the point where the loading of the gas leaving the collector is approximately one grain. Naturally, there are variables effecting this condition. One of these may be the total percentage of ash retained in the furnace. Another is the percentage of carbon in the escaping fly ash. However, in most cases the percentage of carbon in the fly ash exceeds the percentage of ash retained in the boiler setting, or at least balances it.

Under such conditions the collector efficiency has little apparent bearing on the collector discharge. While it is found that with a low efficiency collector the amount of fly ash recirculated through the furnace is considerably less than with a high-efficiency collector, the amount of fly ash escaping is practically the same in both cases. The important point is that, under the same conditions of ash content of coal, the amount of fly ash recirculated with a high-efficiency collector will be several times that recirculated with a low-efficiency collector. These conditions may be briefly outlined as follows:

On a 50-per cent efficient collector the recirculated loading is indicated as approximately twice that of the original loading. On a 75-per cent efficient collector the recirculated loading is indicated at approximately four times that of the original loading and on a 90-per cent efficient collector the recirculated loading is indicated at approximately ten times that of the original loading.

To visualize properly these conditions let a specific case be assumed where, on a pulverized-coal installation, complete with air-heater, induced-draft fan and fly-ash collector, the gas loading is one grain per cubic foot, the collector has an efficiency of 80 per cent and the carbon content of the fly ash is 50 per cent. Recirculation is put into effect for the recovery of the latent heat of this carbon. As the collector has an efficiency of 80 per cent, four-fifths of the fly ash is returned to the furnace. One-fifth escapes to the atmosphere.

The original loading, based on the amount of coal burned and the ash content of the coal, was one grain. As the amount of coal burned per pound of steam on any one installation is fairly constant, the primary loading may be considered as constant. To this there has then been added four-fifths of a grain, thereby increasing the loading of the gases to the collector to one and four-fifths grains, less that amount of carbon contained in the fly ash burned on the first pass. On the basis of 80 per cent efficiency for the collector there is then returned to the furnace something under 1.44 grains with 0.36 grain escaping the stack.

Irrespective of what percentage of the carbon in the fly ash is actually burned, as recirculation continues the loading may continue to increase, and in those cases observed, has increased up to the point where the amount escaping the stack is approximately equal to the original percentage of the ash in the total coal burned and the amount of fly ash passed through the boiler setting is approximately five times that of the original loading, before recirculation was put into effect. This condition may be checked by tests at the vital points.

Even when assuming that there is a material reduction of the percentage of carbon in the fly ash, for example, that the original 50 per cent has been reduced to 20 per cent, there still remains, for consideration and proof as to possible gain, the question as to how it is possible to obtain any increased boiler efficiency by continued recirculation of a fly ash having four parts ash and one part carbon.

To illustrate this point more clearly, and from another angle, assume two boilers of the same size and design and equipped with the same auxiliaries. Both of these boilers are fired with the same grade of coal, both are equipped with collectors operating at the same efficiency and analysis of the fly ash in both collectors indicates the same percentage of carbon. On one boiler there is no fly-ash recirculation; on the other there is.

Comparison of the furnace conditions by visual observation indicates that a relatively clear atmosphere exists in the non-recirculating furnace, objects being clearly visible on the opposite wall. In the furnace having recirculation a distinctly hazy atmosphere exists, to the extent that visibility is greatly reduced. This is caused by the increased cloud of fly ash introduced to the furnace by recirculation, and gives rise to the following questions:

What is the increase in air volume required to handle this greatly increased fly-ash load and what is the heat absorption of this air?

What is the increased cost of maintenance of the furnace walls, due to increased slagging?

What is the actual heat transfer condition, due to greater ash accumulation on the boiler tubes?

What is the additional operating and maintenance costs required for the soot blowers, and what is the increased percentage of erosion to the boiler tubes because of prolonged soot-blower operation?

What is the possible heat transfer loss and erosion in the air heaters?

What is the increased maintenance and operating costs of the induced-draft fan, because of the increased loading of the gases, with a highly vitrified ash?

For the same reason, what is the additional maintenance and operating costs on the fly-ash handling equipment from the collector to the boiler?

And, what effect has this additional ash and air on burner operation?

Fly-ash collectors are almost invariably installed for the elimination of a nuisance. With the increased discharge from the collectors, how much is the nuisance intensified?

When these questions are analyzed and the correct answers obtained, the actual value, plus or minus, of fly-ash recirculation may be established.

There is one additional point which, while it has no actual bearing on the value of fly-ash recirculation within the boiler system, has a decided bearing on plant economies as a whole. In plants situated in some districts the ultimate disposal of the collected fly ash is often costly. If such ultimate disposal can be effected through recirculation and eventually out the stack, this cost is eliminated.

The question may be rightly asked—if such is the condition, how can this carbon be utilized without increasing the nuisance condition? The only answer is to eliminate the excess carbon at the source through proper design and operation of the furnace equipment and there will be no necessity for recirculation.

Stoker Applications

Applied to stoker-fired installations different conditions are encountered, both in the furnace and in the material to be recirculated.

With pulverized-coal installations (except perhaps in the case of slagging bottom furnaces) there is seldom more than 35 per cent of the ash retained in the boiler setting. The average amount is indicated at about 20 per cent. In stoker-fired installations, however, indications are that the average of ash retained in the boiler setting is well above 75 per cent. This one factor creates a very different condition when recirculation is contemplated.

The cinders are far coarser and with a much higher carbon content. Analysis of samples from various installations shows an average value slightly over 9000 Btu per pound and in some few cases this has been found as high as 11,000 Btu per pound. Such heat content places the cinders in close proximity to the low-grade coals as far as heat value is concerned and their loss may be considered, in most cases, as an equivalent loss in coal.

Dependent upon the class of coal burned, there is a wide variation in the type of cinder. Also, dependent upon the type of stoker used and upon individual operation, there is a wide variation in the amount of cinder escaping the boilers. Consideration of the character of the cinder is important. Very little volatile matter remains in the cinder once it has passed through the furnace. Also, it has been found that the ignition point of some cinder is extremely high, so high in fact, that it cannot be burned readily under ordinary furnace temperatures.

With certain types of stokers, operating at normal loads, many installations exist wherein the actual discharge to the atmosphere is less than $^1/_2$ grain per cubic foot of gas. With other types of stokers the discharge to the atmosphere, when operating under normal loads, will exceed two grains per cubic foot of gas. When operating at high loads the discharge to the atmosphere will be considerably increased on all types of stokers.

Due to the comparatively coarse character of the cinders a much higher terminal velocity is established than for fly ash. This means that a high percentage of the cinder settles within a comparatively short radius of the stack. Investigation has shown that a discharge of one grain per cu ft from a stoker-fired installation may create a more pronounced nuisance in the immediate vicinity of the plant, radius $^1/_2$ mile, than would be caused by a two-grain discharge from a pulverized-coal installation within the same radius.

For recirculation of the cinders there is then to be considered:

1. The heat value and ignition point of the cinder.
2. The amount of cinder leaving the boiler.
3. The method of introduction to the furnace which is, in turn, dependent upon the type of stoker used.

Where these conditions are favorable, or may be favorably arranged, good results may be obtained. However, when the conditions are not favorable, the cost of recirculation will more than offset the advantage gained in heat recovery. The build-up of the loading to the collector and the discharge to the atmosphere may approximate that occurring with fly ash, thereby increasing the possibility of a dust nuisance.

However, as a whole, it is found that there are many cases where cinders have been burned to good advantage without increasing the dust hazard.

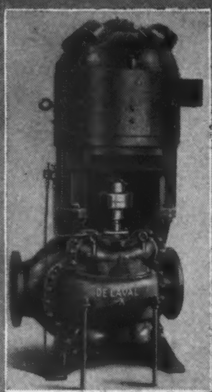
Surveying Solid Fuel Requirements for Public Use

Secretary of the Interior, Ickes, has asked the governors of all the states to aid him in determining the solid fuel requirements of all state, county, municipal and other local governmental agencies as a part of his program to coordinate the supply of solid fuels for the wartime emergency. A survey of the Federal Government's fuel needs is already under way and appropriate steps are being taken to ascertain all other solid fuel requirements.

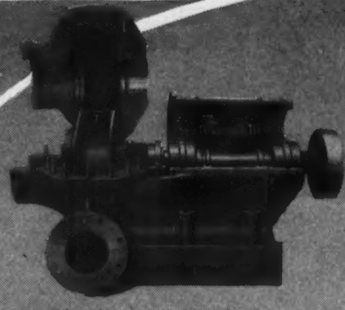
Although not anticipating any immediate solid fuel shortages, the Secretary's action was taken as a precautionary measure. In his letter to the governors he pointed out that coal is a major source of energy for the operation of government-owned and operated utilities, such as water, gas and electric power plants; also, that it is the primary fuel for heating many state hospitals, public buildings, schools, etc., whose continuance in wartime is a necessity.

In the event of a subsequent shortage, this information will constitute basic data upon which to apportion solid fuels to such consuming agencies.

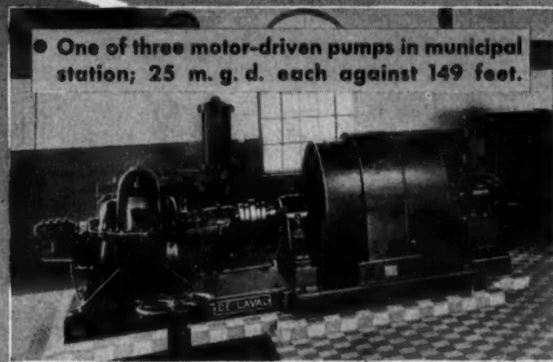
A DE LAVAL PUMP
to fit your job



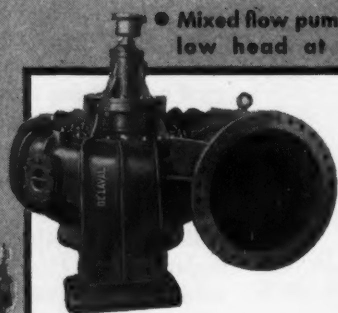
• Condenser circulating pump for salt water; bronze bearings, monel shaft and impeller.



• Clogless pump, for paper pulp, sewage, etc.

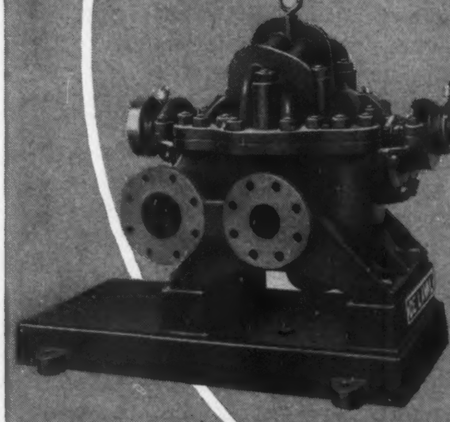


• One of three motor-driven pumps in municipal station; 25 m. g. d. each against 149 feet.

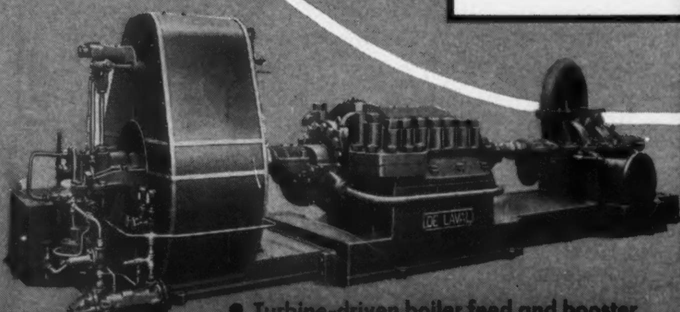


• Mixed flow pump, for large volume against low head at standard motor speed.

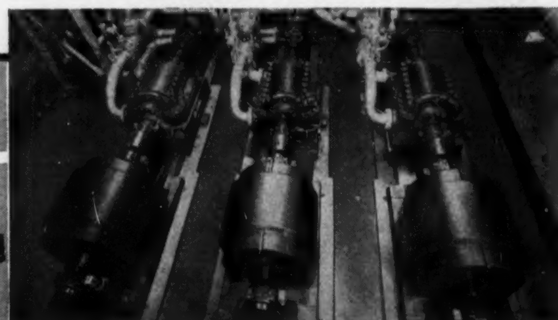
INFINITE combinations of capacities, heads and speeds require careful design of each centrifugal pump to insure best efficiency and desired operating characteristics. • Where a liquid having a destructive effect on standard materials is to be handled, the life of a pump can usually be increased many times over, and its average efficiency improved, by using special alloys for casing, impeller, sleeves, wearing rings and shaft. Only by careful study of user's conditions are the best results to be obtained. • State your pumping requirements in detail so that the engineers of our Centrifugal Pump Department may give you all the benefit of their extensive experience. Ask for Leaflet P-3220.



• Opposed impeller pump; compact; perfectly balanced; only two pairs of wearing rings.



• Turbine-driven boiler feed and booster unit; 1455 g.p.m. against 1186 psi.



• Multistage de-scaling pumps; 1200 g.p.m. each against 1200 psi. at 1750 r.p.m.

HYDRAULIC INSTITUTE U.S.A. MEMBER

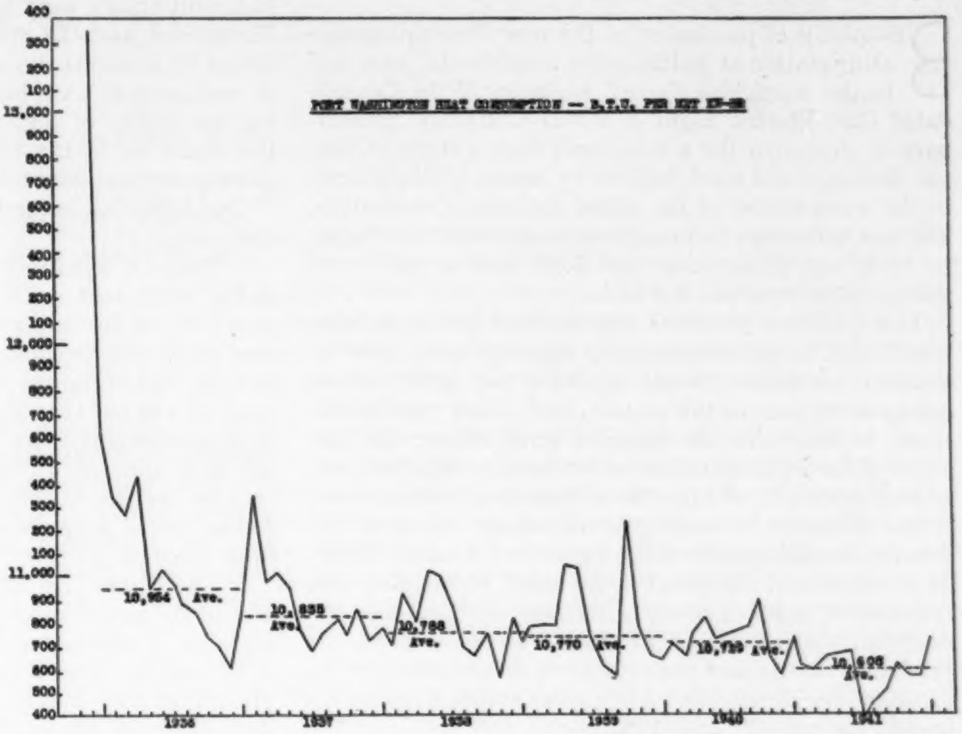
DE LAVAL *Steam Turbine Co.*
TRENTON, N. J.

MANUFACTURERS OF TURBINES . STEAM, HYDRAULIC; PUMPS . CENTRIFUGAL, PROPELLER, ROTARY DISPLACEMENT, MOTOR-MOUNTED, MIXED-FLOW, CLOGLESS, SELF-PRIMING; CENTRIFUGAL BLOWERS and COMPRESSORS; GEARS . WORM, HELICAL; and FLEXIBLE COUPLINGS

Port Washington 1941 Operation

TWO stops, scheduled several months previously and totaling 12½ days, were the sole interruptions to continuous service during the sixth year of Port Washington's operation. No important troubles or major dismantlings for inspection occurred.

The first outage was in May after four months under load, and lasted 8½ days. Subsequent operation continuously throughout the four spring and summer months was terminated by a four-day week-end inspection in September in preparation for the present winter run. Thus, the plant operated 96.6 per cent of the year, and was out for maintenance and inspection 3.4 per cent of the elapsed time.



USE AND AVAILABILITY DATA

	1941 Boiler	1941 Turbine	1941 Plant	6-Year Average Boiler	6-Year Average Turbine	6-Year Average Plant
Use Factor, $\frac{\text{Service hours}}{\text{Period hours}}$	96.6	96.6	96.6	89.4	89.3	89.3
Hourly Output-Capacity Factor, $\frac{\text{Ave. hourly output}}{\text{Rated hourly output}}$	67.1	76.4	76.4	61.9	69.6	69.6
Annual Output-Capacity Factor, $\frac{\text{Annual output}}{\text{Annual rated output}}$	64.8	73.8	73.8	55.5	62.2	62.2
Annual Demand Factor, $\frac{\text{Demand hours}}{\text{Annual hours}}$	100	96.6	100	94.5	95.6	98.3
Demand Availability, $\frac{\text{Service hours}}{\text{Demand hours}}$	96.6	100	96.6	95.4	94.3	91.5
Annual Availability Factor, $100 - \frac{\text{Repair hours}}{\text{Annual hours}}$	96.6	100	96.6	93.9	95.0	91.0

Higher system loads increased the total output 12 per cent above 1940 and avoided the need of week-end outages, but did not eliminate occasional low loading caused by hydro interconnections on the system. Frequent full-load 80,000-kw output was required throughout the last four months, increasing the station heat consumption.

Better economy, to the extent of 1.1 per cent, was attained for this sixth year over that during the fifth year, thus continuing the unbroken annual improvement trend. Net heat consumptions were 10,729 and 10,608 Btu per kwhr for 1940 and 1941, respectively. The lowest monthly station heat consumption during 1941 was 10,395 Btu per kwhr net.

[Through the courtesy of the Wisconsin Electric Power Co., we are able to supply readers with mimeographed copies of "Averages of Daily Operating Data"—EDITOR.]

OPERATING PERIODS AND REASONS FOR OUTAGES—1941

No.	Date Started	Date Finished	Hours Run	Kwhr Generated	Outage Hours	Outage Reason
59*	12/27/40	5/10/41	3,216.32	192,754,000	203.27	General scheduled inspection of boiler
60	5/18/41	9/ 3/41	2,598.93	160,911,000	97.00	General scheduled inspection of boiler
61	9/ 7/41	12/26/41†	2,644.48	163,244,000		
Total	12/27/40	12/26/41	8,459.73	516,909,000	300.27	
Total (6 yr)	11/22/35	12/26/41	47,889.92	2,658,847,500	5,558.08	

* This operating period started 12/23/40.
† Still in operation.

OUTPUT AND HEAT CONSUMPTION DATA

Year	Month	Output, KwHr Gross	Output, KwHr Auxiliary	Output, KwHr Net	Heat Consumption, Btu per Kwhr Gross	Heat Consumption, Btu per Kwhr Auxiliary	Heat Consumption, Btu per Kwhr Net
1941	January	44,824,000	2,192,510	42,631,490	10,120	520	10,640
	February	41,252,000	2,002,487	39,249,513	10,103	515	10,618
	March	45,405,000	2,205,254	43,199,746	10,168	519	10,687
	April	41,339,000	2,059,990	39,279,010	10,178	534	10,712
	May	32,434,000	1,632,155	30,801,845	10,177	539	10,716
	June	44,847,000	2,173,463	42,673,537	9,891	504	10,395
	July	46,628,000	2,299,826	44,328,174	9,949	516	10,465
	August	46,335,000	2,343,949	43,991,051	9,984	532	10,516
	September	38,277,000	2,003,256	36,273,744	10,097	558	10,655
	October	47,059,000	2,378,713	44,680,287	10,067	536	10,603
	November	42,998,000	2,201,188	40,796,812	10,059	543	10,602
	December	45,511,000	2,310,633	43,200,367	10,199	545	10,744
1941	12 Months	516,909,000	25,803,424	491,105,576	10,079	529	10,608
1936–41	72 Months	2,621,248,000	135,696,424	2,485,551,576	10,215	557	10,772
1935–41	75 Months	2,662,415,000	138,456,724	2,523,958,276	10,232	561	10,793

Novel Tests for Stack Height

BECAUSE of proximity of the new Riverside generating station at Baltimore to a residential area and to the municipal airport, engineers of the Consolidated Gas, Electric Light & Power Company, preliminary to designing the stacks, undertook a study of flue-gas discharge and stack heights by means of model tests in the wind tunnel of the Allied Aviation Corporation. The test procedure and results were described in a paper by H. L. von Hohenleiten and E. F. Wolf at the recent Annual Meeting of the A.S.M.E.

Three distinct phases of this problem had to be analyzed: (*a*) It was necessary to establish what wind or weather conditions would produce the most serious smoke annoyance at this station, and, under these conditions, to determine the required stack height; (b) the effect of the addition of successive units to the plant had to be considered; and (*c*) due to stack-height limitations, it was necessary to investigate all possible means of improving the dissipation of flue gases, such as stack design or arrangement, shielding of the stack or building and increase of stack velocity. Because of the induced-draft-fan system, height of stack was not a factor in producing draft, and with Cottrell precipitators to be installed, the dissipation of flue gases rather than smoke became the primary consideration.

Although theoretical analysis and previous work had indicated that model investigations should produce sufficiently reliable results for predetermining the required stack height, it seemed desirable, as a preliminary step, to establish further proof of the validity of such tests. Accordingly, a simplified model of the company's Westport Station and surrounding property was tested to observe the relationship between the model smoke patterns and the actual smoke patterns at the existing plant. It was found that the model satisfactorily reproduced the actual path of smoke from the Westport stacks.

Next, three models of the Riverside Station were tested, namely, a single-unit, a three-unit, and a six-unit model, the last representing the probable ultimate development. These models, constructed of wood, were placed on a turntable erected between the throat and bell of the wind tunnel. The miniature stacks were adjustable in height and were equipped for variable discharge of air up to 70 ft per sec. Ammonium chloride was employed to produce a dense white discharge from the stacks to simulate flue-gas. For the single unit this was supplied through a one-inch rubber hose from a blower driven by a variable-speed motor and the multiple-unit stacks were fed through a plenum chamber. Turbulence and the area around the building was explored by means of threads and by flake mica distributed at various points, the path of the particles of mica showing the regions of turbulence, the direction of flow and the character of the vortexes. Both still and motion pictures were made of the fumes.

The following general conclusions were drawn from these tests:

1. Since it was necessary in this case to select a stack height consistent with requirements dictated by the proximity of the airport, and, at the same time, to insure reasonable freedom from a smoke nuisance, a compromise had to be reached. From practical considerations, it was felt that the performance at wind velocities of approximately 20 mi per hr should govern, because of the large number of days during a year that such wind velocity prevails at this site. Velocities in excess of this will definitely produce a greater degree of downdraft, but these stronger winds occur with diminishing frequency.

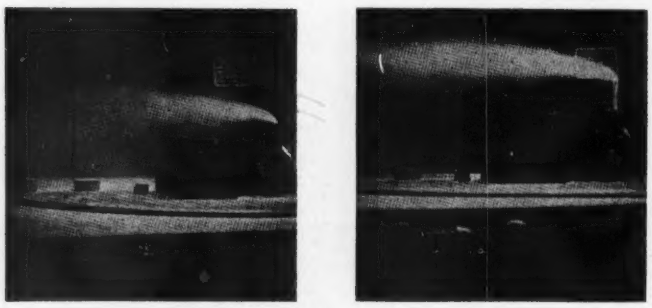
2. With any low stacks, smoke was carried down around the model and close to the ground at the prevailing wind velocities, as would be expected, the amount of downdraft diminishes with increasing stack height. The model tests indicated that it is necessary to have a stack height of approximately 157 ft above ground (1.31 times the height of the boiler-room monitor) in order to reduce the smoke nuisance to reasonable limits with a 20-mi per hr wind. Even at this stack height, there is noticeable downdraft of smoke around the model within limited angles of wind direction, also at this height, some annoyance from sulphur dioxide can be expected on days when very high wind velocities occur.

3. The benefits from high stack velocities are found to be distinctly worth while for flue-gas dissipation. The tests indicate that a stack velocity of 60 ft per sec. is desirable at this plant.

4. Annoyance from downdraft may be expected to increase somewhat with the addition of each unit.

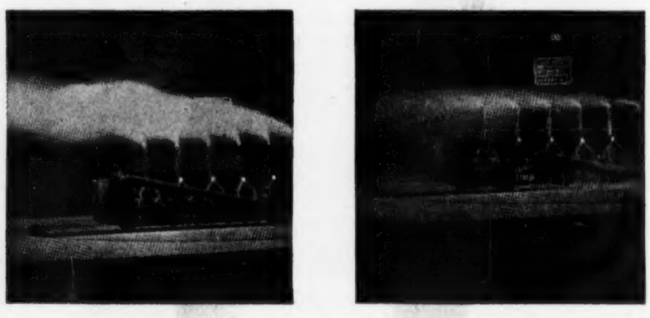
5. None of the large number of special stack designs or shields that were tried out showed sufficient merit to justify use at this plant.

6 It is well to point out that the results obtained by these model tests apply specifically only to that prototype for which the model is designed, as the influence of surrounding structures alters the turbulence pattern.



139 ft 175 ft

Fig. 1—Effect of stack height, single-unit model, wind velocity 20 mi per hr and stack velocity 50 ft per sec



10 mph 40 mph

Fig. 2—Showing effect of wind velocity with six-unit model and stack height of 167 ft

Boiler Feed-Pump Operation

By WILLIAM MADDOCK*

Some practical suggestions, based on the author's experience, dealing with the maintenance of minimum flow, stability of operation and air binding due to intermittent operation.

FOR the safest and most stable operation of boiler feed pumps, one of the most important considerations is the provision for, and maintenance, of a minimum flow for cooling and the prevention of steam binding. Naturally the question foremost in the mind of the operator is, "How much is considered as being the necessary minimum flow?" The answer usually given by various authorities will average around 5 per cent of the full load rating of the pump. Nor, according to the writer's observation, should the temperature rise of the water going through the pump exceed 30 F. For all practical purposes the value may be calculated from the dead-head motor horsepower. This assumption takes the horsepower at dead head to be equal to the losses at the minimum flow rating, and puts all pump losses in the pump runner. Neither assumption is correct but in the first case, it should vary less than 1 per cent, and in the second, not more than 3 to 5 per cent.

For example, a 1000-lb pressure, 300,000-lb per hr pump might have a dead-head load of 200 hp. The Btu going to the water each hour would then be 200 × 2545, or 509,000 Btu per hr. Limiting the rise to 30 F, the flow should not be less than 17,000 lb per hour. By the 5 per cent allowance, the figure would be 15,000. The value of the 30-deg limit suggested cannot be justified by any mathematical treatment but has been arrived at by inspection of the curves of the temperature rise in various pumps. A typical high-pressure feed pump curve, Fig. 1, shows that the temperature begins to increase rapidly after reduction below the 30-deg point. Anything that would tend to cause even a slight reduction in flow might cause serious overheating, if too close a margin were originally chosen. In case of any doubt, each pump temperature rise should be calculated or obtained from the manufacturer, and a minimum flow value chosen that would not be unduly affected by minor variation.

There has been some discussion as to whether the bypass flow should be continuous or only for low flow operation. Some try to justify the expense of flowmeter type regulation on the basis of power saved. If a feed pump takes as much as two per cent of the power output, and the bypass flow takes two per cent of the feed pump input, then the power that is under question amounts to $^4/_{100}$ of one per cent of the total. Much more than this is wasted in the throttling process of feed control alone.

From the safety standpoint it would be well to run the bypass continuously and its cutoff could be neglected if the extra pump capacity is not needed for full-load operation. It must be said that, if this 5 to 10 per cent of pump capacity is seriously needed when the pump clearances and performance are standard, then the margin of safety in the plant is entirely too close. However, should this be the case, it will be necessary to make provision for the shutting off of the by-pass flow once the minimum normal flow is established. Throttling diaphragm motor valves, controlled from flowmeters or differential orifices, is one method, although expensive, and it may take considerable maintenance. Long drilled orifices are more satisfactory than the plate type and either are less expensive to replace than valve seats. These orifices, put in series with an electric shutoff valve controlled from feedwater flowmeter contacts or from a cam contact on the turbine governor, make a simple foolproof installation. So much for the protection of pumps from overheating due to the effects of churning.

Most other pump troubles arise from the suction design or installation. Rarely does a pump correctly in-

* Mechanical Engineer, Naval Air Base, Honolulu, T. H.

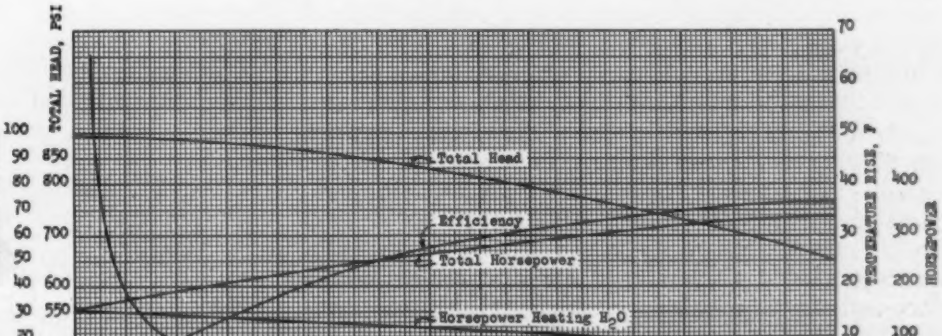


Fig. 1—Feed pump characteristics; at 300,000 lb per hr, 600 lb per sq in.

stalled fail to perform as it was designed. Probably the most stable of all feed pumps are those that take their suction from elevated hotwells or deaerating heaters working at or near atmospheric pressures. This gives a surge and storage arrangement to take up the variation between the feedwater and steam flows. This same idea is used in connection with heaters working at varying bleed pressures, but all too often the elevation head cannot be made great enough to stabilize the suction conditions under sudden large load changes.

For instance, suppose at full load a deaerating heater is receiving bled steam at 20 lb per sq in. gage and the temperature of the water is 259 F. Fig. 2 shows this saturation point on the lower curve. The upper curve was calculated to allow a 10-deg F margin of safety plus

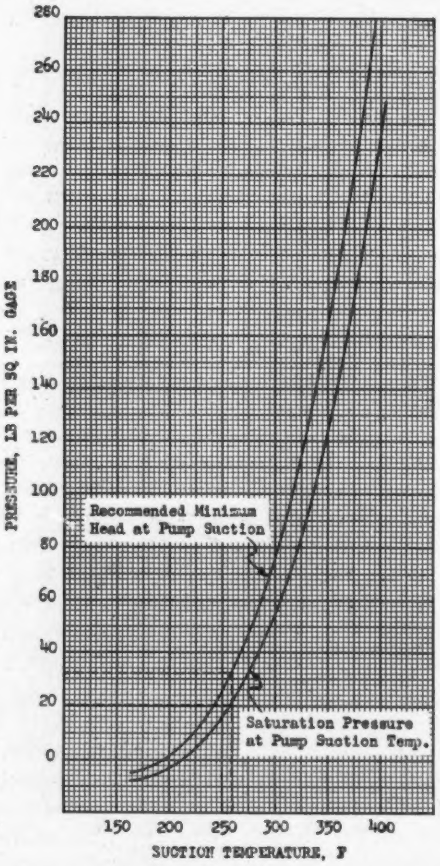


Fig. 2—Boiler feed suction pressures

Calculated to give 10 deg F margin and for 10 ft per sec eye velocity

enough extra elevation head to give a velocity head of 10 ft per sec in the suction eye. From this upper curve it will be noted that a total of 32 lb per sq in. gage is needed above the bleed pressure. Let something happen to suddenly reduce the load and see what happens. The bleed pressure may drop to below atmosphere but, regardless of how far it drops, it is likely to be considerable. Any condensate or flow to the heater will tend to chill the steam space and cause a reduction in pressure there, also. Boiling of the water begins to take place and the process is increasingly progressive downward because the space taken by the steam reduces the weight or pressure at the lower elevations. When vaporization takes place at the pump suction, the first stage becomes steam bound; this causes a reduction in pump

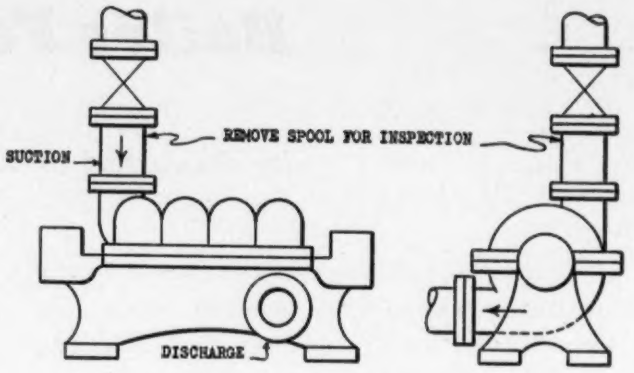


Fig. 3—Suction in top of pump case

output pressure and it can no longer pump against the boiler pressure.

This, in turn, has the same effect as closing the discharge valve, and the final stages become bound. The evolution is amazingly rapid and pump runner seizure has been known to result in less than three minutes from the start of the loss in load. In order to eliminate this possibility, it would be necessary to provide an elevated head of 23 ft for each 10 lb per sq in. that the pressure of the deaerator might drop, in addition to that shown by the upper curve of Fig. 2. Should this be impractical, some provision could be made to automatically admit cooler water to the feed pump suction in case of sudden load drops.

From an operator's point of view another source of trouble is normal air binding due to intermittent operation. Such trouble is overcome in condensate pumps by large vent or equalizing lines and the same method used to some extent on pumps with pressure at the suction. It surely appears that if a fairly large vent line from the top of the pump inlet scroll will cure most air binding, that this should be the logical place to put the pump suction. It would be especially useful at times to have a condensate pump that had the suction drop right on top of the pump, if for no other reason than to make room under the condenser. But to get back to feed pumps, most of their suction lines come from above, too, and the consolidation of the vent line and suction into one would preclude the possibility of air binding in the suction scroll. Fig. 3 shows a sketch of what such a pump might look like.

In the cylindrical-shell type the location of the suction would not make any difference in the inspection or repair of the pump, and in the split-case type the time necessary to remove the low-pressure spools would be negligible compared to the total time required. It is not known for sure but it is possible that with such a large line, ebullition or boiling might be able to take

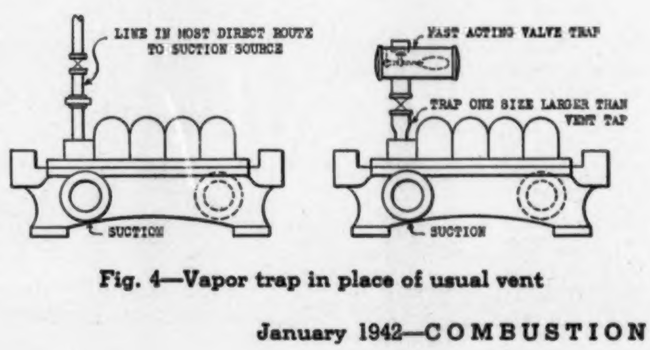


Fig. 4—Vapor trap in place of usual vent

place upward at the same time the water flow was downward, leading to increased stability of the pump under fluctuating loads.

But more about what to do in present installations. In one case where the equalizing line was deemed necessary, the line would have not only been unsightly but impractical. It was suggested that a trap might work. A fast-acting trap that had been designed for large volumes of petroleum vapor was selected because of its small physical size and large air capacity. The 2-in. trap was less than 15 in. long and 8 in. in diameter. The installation was made as in Fig. 4, and was tested by putting a compressed air line on the test gage connection at the pump suction. The suction pressure was 18 lb per sq in., and the air pressure, about 80 lb. With the $^1/_4$-in. air line wide open, the trap discharged the air fast enough so that the pump did not stop delivery. This same trap has been known to discharge steam vapor after sudden deaerator pressure drops. However, it has not been relied on as a remedy against steam binding although there has been no actual evidence that it would not be adequate. The trap has much greater capacity for vapor removal than has the equalizing line. The acting force in the vent line is the difference in fluid density, and the long line full of water offers considerable resistance to the flow. On the other hand, the trap has the difference between the suction pressure and atmosphere with very short lines.

A good vapor trap installed on a pump with a submerged suction, coupled with a continuous bypass eliminates hand priming, increases stability and leads to "sweet running" pump units.

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I MOVE OIL

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in small space

•

De Laval-IMO Oil Pumps

for lube and fuel oil and for hydraulic pressure service pack great capacity into small space. The one shown, delivering 700 g. p. m., occupies only 30 in. square of floor space. It has only three moving parts and runs at standard motor or turbine speeds. Built in all capacities and for all pressures.

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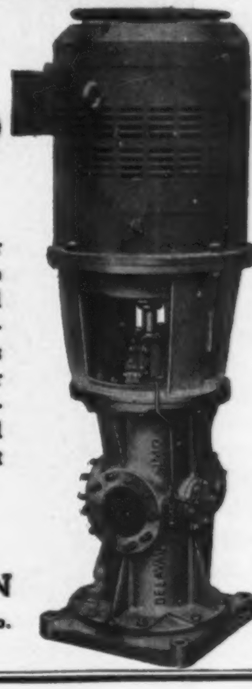
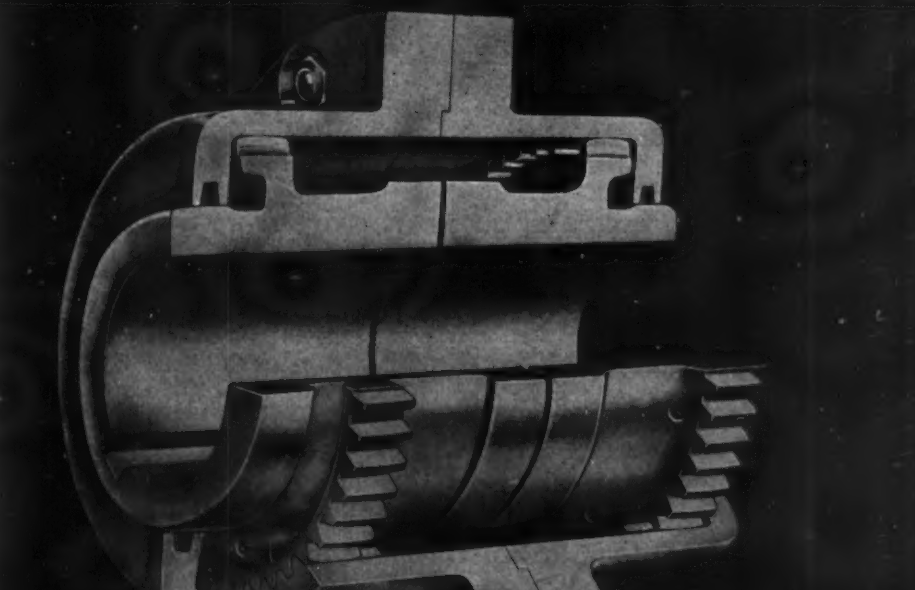
of the De Laval Steam Turbine Co.
Trenton, New Jersey



POOLE



A COPY OF CATALOG GIVING FULL DESCRIPTION AND ENGINEERING DATA SENT UPON REQUEST.

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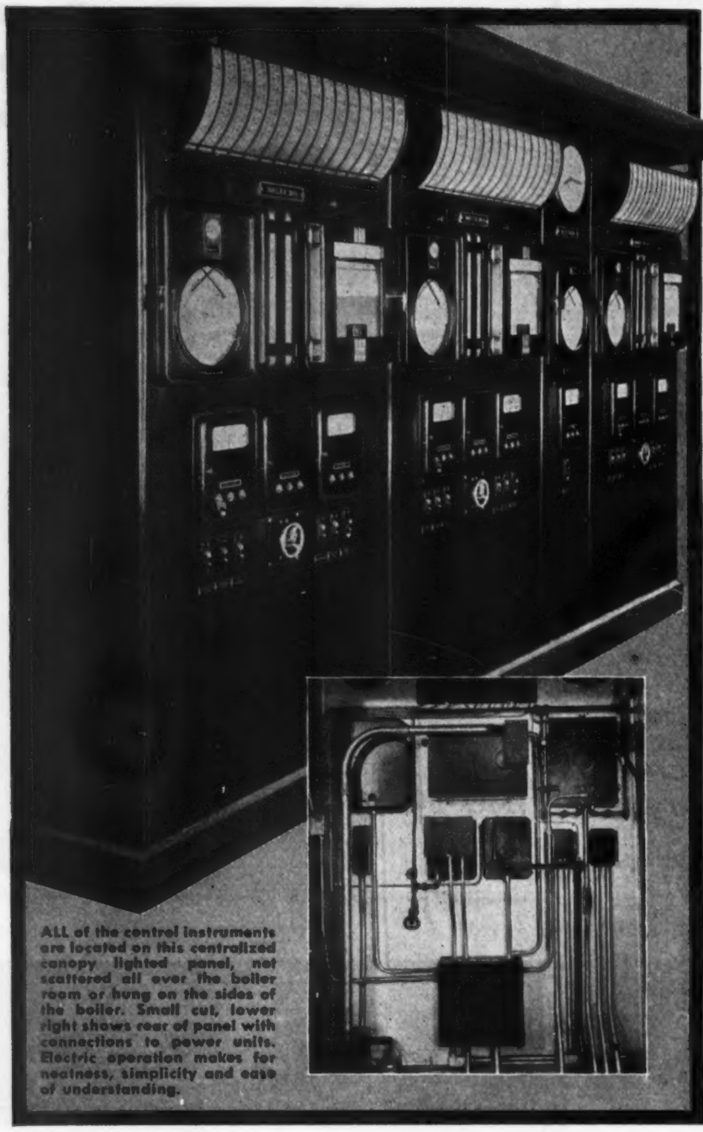

ALL of the control instruments are located on this centralized canopy lighted panel, not scattered all over the boiler room or hung on the sides of the boiler. Small cut, lower right shows rear of panel with connections to power units. Electric operation makes for neatness, simplicity and ease of understanding.

Electric

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*Burning Pulverized Anthracite**

By C. H. FRICK
Plant Betterment Engineer
Pennsylvania Power & Light Co.

The author reviews the experience of his company with pulverized anthracite at the Pine Grove Generating Station and briefly describes the high-pressure installation of two units now on order for the Hauto Station. General considerations governing the use of anthracite in pulverized form are discussed.

PENNSYLVANIA Power & Light Company is the largest single user of anthracite. In order to supply the gas, electric and steam-heat service, it requires 27,000 tons of large sizes, 594,000 tons of No. 3 buckwheat, 753,000 tons of No. 4 buckwheat and 146,000 tons of still smaller sizes, making a total of 1,520,000 tons per year.

There are now 108 anthracite-fired boilers in the Company's power plants, varying in size from approximately 4000 to 18,000 sq ft of heating surface. Two just recently put into service are each capable of producing 185,000 lb of steam an hour. These, however, are stoker fired, and thus far are the largest anthracite-burning boilers in service.

At present three of the larger boilers are fired by pulverized anthracite and there are two larger boilers now on order that will be similarly fired. These will operate at about 1325 lb pressure with 930 F total steam temperature and each will be capable of producing 365,000 lb of steam per hour. It is on the basis of the existing installation that experience was secured which governed the decision to again use pulverized fuel.

History of Burning Pulverized Anthracite

The first experimental plant to burn pulverized anthracite was a small two-boiler installation belonging to a coal company which was started in 1918. This plant was abandoned in 1928, after sufficient proof had been established that low-volatile coal could be burned in pulverized form in a properly designed furnace. In 1920 and 1921, the same coal company erected a larger plant containing twelve pulverized-coal-fired boilers of 500 and 600 hp, which plant is still in operation. It was one of the first power plants designed to utilize anthracite slush, which at that time constituted all sizes below No. 3 buckwheat, previously considered waste incidental to anthracite mining. This plant produces steam and electricity for direct use in the coal mines, the coal being comparatively soft and therefore easy to grind.

Pine Grove Installation

Although these early installations and tests showed the practicability of using anthracite in pulverized form, no large installation was made until Pennsylvania Power & Light Company decided to extend its Pine Grove Plant by adding three large pulverized-coal-fired boilers, which were put into service early in 1927.

The original milling equipment at Pine Grove consisted of four 70-in. screen-type mills each driven by a 350-hp motor. These, except for gear drives, were larger units but identical in type to the 42-in. mills in the coal company plant previously mentioned.

Later one of these mills was converted to an air-swept type which depended for control of fineness on recirculation of the product. It partially overcame one of the inherent deficiencies of the screen-type mills, in which there was no continuous control of fineness. Subsequently, two of the original screen mills were removed and two horizontal air-swept ball-and-tube mills installed. These are 8 ft in diameter by 17 ft long, and normally supply the entire pulverized fuel requirements.

Pulverized coal, transported by air through these mills, is collected in cyclones from where it is pumped through pipe lines using air as the transport medium, to bins of 120 tons capacity at each boiler. From these it is fed by mechanical feeders to the burners.

All the vents from the various bins, cyclones, etc., are connected to a common vent house, used as a settling chamber for the coal dust from which the vented air, with a small amount of entrained coal, is taken to the suction of the primary air fans, so that no coal is lost to the atmosphere. There are no bag filters or anything of this nature used in this plant.

Each of the three pulverized-coal-fired boilers is of the single cross-drum type, having about 17,700 sq ft of heating surface proper. Protection to the rear wall refractories is afforded by a water wall connected into the boiler-water circulation.

Originally, no cooling surface was planned for the bottom of the furnace, except that the first boiler had a water screen several feet above the bottom of the furnace. For reasons explained later on, new water-cooled furnace bottoms were installed, consisting of tubes at an angle of approximately 45 deg, covered with cast-iron blocks, and connected into the boiler-water circulation.

Each boiler is equipped with an air preheater, which raises the temperature of the secondary air from room temperature to approximately 550 F. This secondary air is about 80 per cent of total requirements. The boiler side walls are hollow, and the front walls have staggered air ports. The secondary air passes through the hollow side walls to keep down refractory temperatures and is discharged through the ports in the front walls to complete combustion of the coal.

The coal is fired vertically downward, so that the heat of combustion travels up to ignite additional coal com-

* Excerpts from paper presented at the Joint A.S.M.E.-A.I.M.E. Fuel Meeting, Easton, Pa., October 30–November 1, 1941.

ing into the furnace. This is the only way anthracite can be fired. The ignition temperature for pulverized anthracite is about 300 deg higher than for bituminous; therefore, it is not possible to be as liberal in the use of water-wall cooling with the former as with the latter.

Operating Experiences

Shortly after the plant was put into operation high maintenance of mills and low capacity resulted. That the various mill changes made have produced results is evidence from the accompanying table.

PINE GROVE ANNUAL PREPARATION PLANT DATA

Year	Size per cent through 200 mesh screen	Pulverized Coal per mill-hour, net tons	Kwhr per net ton pulverized	Mill maintenance per net ton, cents	Total cost per net ton, cents
1928	69.2	8.4	28.5	46.7	51.0
1929	73.3	9.3	29.8	28.8	36.1
1930[a]	74.0	10.3	33.1	43.2	52.1
1931	76.7	11.7	35.5	13.9	26.6
1932	75.4	11.6	36.0	20.4	22.2
1933	75.8	12.7	34.7	9.1	21 9
1934[b]	76.9	12.8	34.9	18.6	27.8
1935	76.6	12.2	34.1	4.8	11.4
1936	75.2	11.8	33.4	2.2[c]	7.9[c]
1937	76.2	12.3	31.3	8.5	13.5
1938	76.5	12.0	33.2	9.3	17.4
1939	77.2	12.5	34.5	6.2	13.7
1940	77.6	12.8	36.2	6.7	14.1

a First ball-and-tube mill in service.
b Second ball-and-tube mill in service.
c Low due to credit for material returned to stock.

Generally, since 1934, all preparation-plant equipment has given satisfactory service at low cost. Certain limitations are required, such as keeping moisture of the pulverized fuel to 1 per cent or less, to prevent arching in bins. Except for higher grinding costs and the energy consumption, as is to be expected, there is no marked difference between the preparation of anthracite and bituminous coal. However, anthracite has one distinct advantage, namely, there are no explosion hazards, due to its low volatile content.

The dryers as originally designed did not retain the coal long enough, nor was there sufficient mixing of coal and air to produce thorough and economical drying. The installation of additional cascading angles and retarding baffles improved results materially. To insure thorough drying under all initial moisture conditions, it was found necessary to maintain the exit coal temperature at about 300 F with a dryer exit gas temperature of about 225 F. These temperatures are considerably higher than allowable in drying bituminous coal.

The boiler furnaces were originally designed for a maximum heat release of 16,000 Btu per cu ft per hr. This was conservative in order that capacity could be maintained with high-ash coal at little sacrifice in boiler efficiency. Various tests conducted from time to time have shown this to be true.

Trouble was experienced when the first boiler went into service with ash sticking to the bottom of the furnace (fusion temperature about 2450 F). It required from 2 to 5 hr daily to loosen and remove the ashes from the floor so they could be dumped through the gates. It was necessary to operate with high excess air so as to prevent excessive temperatures, which would slag up the entire screen, necessitating taking the boiler out of service for cleaning.

This condition could be alleviated by reducing the flame length well above the hearth screen. However, by so doing the decreased flame travel produced excessive carbon losses in the stack gases and transferred the slagging trouble to the boiler tubes themselves. This experience immediately warranted change in design of the remaining two boilers to include Bailey furnace bottoms. Their successful performance later justified a similar installation in the first boiler installed.

After a period of test with varying air distribution through the front wall ports, operation became very well stabilized so that ash removal was simply a matter of opening the ash gates periodically. Boiler-tube slagging is effectively reduced by soot blowers in the first pass, so that continuous service periods of from two to three months is not out of the ordinary for these boilers

Present practice is to maintain a coal fineness of about 77 per cent, through 200-mesh screen, which has been found to be most economical for this particular installation. Successful operating results are secured by limiting the variation in fineness to a narrow range, and this is accomplished by the operators taking hourly samples of pulverized fuel, which are immediately screened and mill draft adjustments made if necessary.

The total preparation plant power requirements amount to about 3 per cent of the main unit capacity supplied, and because this plant has the storage system the preparation plant is shut down during peak-load hours.

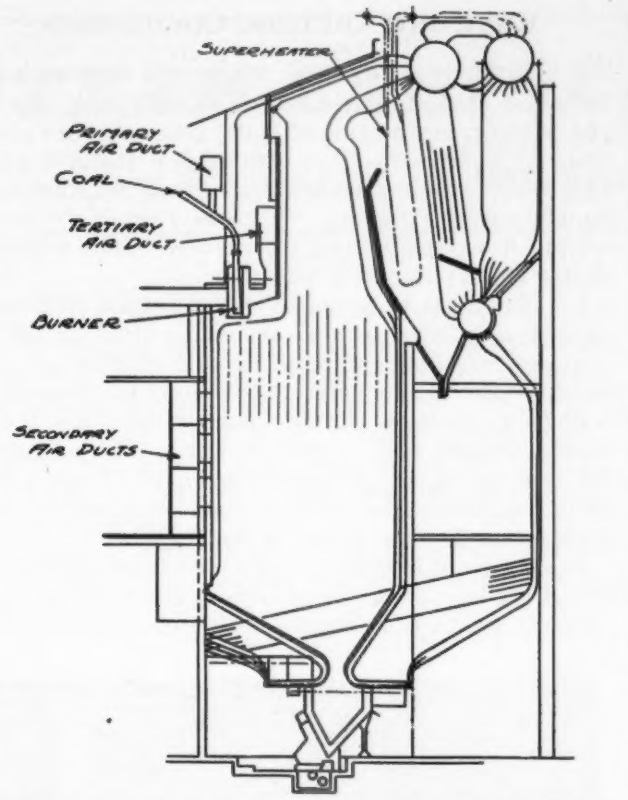
Boilers are started from the cold state by use of several torches, which burn either kerosene or light oil and which are inserted through the front walls of the furnace. They are left burning only long enough to ignite the coal which is turned on gradually from the overhead burners. Invariably the torches are removed before the boiler is up to pressure. Once ignition is secured, maintaining it from about 90,000 lb to 180,000 lb of steam per hour is possible without using torches.

New Developments at Hauto

As previously mentioned the Company has recently contracted for the two largest boilers ever designed to burn anthracite. These will burn it in pulverized form. After considerable study of the relative merits of the unit system versus the bin or storage system, it was decided to use the storage system similar to that at Pine Grove. Advantages in favor of continued use of the bin system in this case are:

1. The benefits in capacity to be gained, by consideration of shutting down the preparation plant over station peak hours. This will amount to 1300 kw or about 4 per cent of the topping unit capacity for which these boilers will supply steam.
2. One shift preparation plant labor will be saved.
3. Any failure of preparation plant apparatus will not immediately affect the boiler output, because the prepared fuel in storage bins of 240 tons capacity is good for 12 hr at maximum conditions.
4. Better control of the product since milling conditions can be set, independent of boiler requirements, for continuous maximum capacity consistent with the fineness desired, thereby reducing energy requirements over the unit system, since there is only a variation of about 10 per cent in energy requirements between full load and no load, due to the amount of coal in the mill being only a small per cent of the ball charge.

Reasonable evaluation of these advantages has justified the slightly higher cost of the bin over the storage system in this case.



Sketch of one of the new Hauto boilers which will burn pulverized anthracite

There will be three mills with a total capacity of 57 tons per hour and the two boilers will be capable of burning a total of 40 tons per hour.

As at Pine Grove, the burners will project the coal vertically downward through a short horizontal arch, the point of entrance being about one-third of the distance between the top and bottom of the furnace. Air for combustion will be preheated to approximately 590 F at full boiler load, and a portion of this preheated air, ranging from 5 to 10 per cent will be mixed with the coal streams through seven feeders, each one supplying two burners. Supplementary primary air fans will act as boosters to maintain adequate air pressure at the burners.

Surrounding the coal burners will be tertiary air nozzles, which will supply air amounting to anywhere from zero to approximately 40 per cent of the total air for combustion, as found necessary. The balance of the air will be injected through a series of ports in the front wall of the furnaces served by three horizontal ducts.

Individual control dampers will be installed on the primary air supply of each boiler, likewise on each individual tertiary air supply, and also on each duct of the secondary air supply. The entire installation will be automatically controlled, using inlet vane dampers on the forced- and induced-draft fans, the actuating medium being primarily steam pressure.

Due to size of the units, two forced-draft fans per boiler have been specified to deliver the air through a common regenerative-type air preheater and there will also be two induced-draft fans, so that in case of trouble with either one the remaining unit will enable about 60 per cent of the boiler output to be maintained.

The raw fuel supply is expected to contain approximately 14 to 16 per cent ash (dry basis) and be of such size that all particles will pass through a $^3/_{32}$-in. round-mesh screen. The guaranteed boiler efficiency at full load is 81.5 per cent, with coal pulverized to 85 per cent through a 200-mesh screen. This sizing was specified to insure ample reserve milling capacity.

The furnace volume will be 25,000 cu ft with an anticipated heat release of 20,000 Btu per cu ft of furnace volume per hour. The entire furnace bottom will have fin-type tubes.

The sketch shows a cross-section of one of these boilers.

Considerations for Use of Pulverized Anthracite

In general, the size of raw coal used in a pulverized-anthracite installation is that which is smaller than is practical to burn on stokers, and is usually the size remaining after all such usable stoker sizes have been removed from the raw material. There are millions of tons in banks in the anthracite territory, also much is being currently produced.

The moisture content of small anthracite is usually high, running from 8 to 15 per cent, or even more in some cases, particularly in railroad car deliveries during the cold weather months, when the coal is frozen. This is due to the large amount of water used in its preparation. The smaller the size of the coal, the more moisture it will inherently retain. Very small sizes of anthracite seem to act very much like a sponge, holding a considerable percentage of moisture. Samples of this kind of coal taken on the very hottest summer day will indicate as much as 8 to 10 per cent moisture at a distance of 2 to 3 ft below the surface of the pile. This even applies to coal which has been in storage for a very long time.

This high moisture content presents a handling problem in winter, necessitating a coal-thawing shed, since such coal frozen in railroad cars would entail an unloading cost of from 15 to 20 cents per ton, whereas with proper thawing facilities it can be unloaded for about 25 per cent of this cost.

From an overall standpoint the economic use of such fuel is limited to the anthracite-producing centers or territory adjacent thereto, where large piles of these small sizes are within low-cost transportation zones.

Since the cost per million Btu delivered to boilers includes the cost of pulverization, the question can be raised whether a 4 per cent decrease in favor of utilizing this fuel warrants the increased investment required over a stoker plant for the cheapest stoker fuel listed. There are several reasons for giving preference to burning in pulverized form; these are:

1. The availability of No. 4 buckwheat is limited, dependent largely upon current mine production.

2. There is only about 8 per cent investment differential in favor of stokers, for such an installation as is being considered, because with pulverized firing only two boilers are contemplated whereas with stoker firing, using the largest stokers obtainable for small anthracite, four boiler units would be necessary.

3. The final answer is that pulverization makes usable in the territory a natural resource which would otherwise be wasted, and heretofore not usable by any other means, at a total cost, very close to that obtainable with marketable sizes of limited quantity.

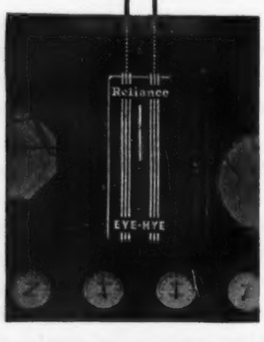
However, every case is a special problem, requiring consideration of all factors involved, before final selection of type of fuel and equipment can be made.

The Reliance Safety Team gives you *accident-preventing* water level supervision, *doubly sure,* at low cost . . .

YOUR POWER PLANT demands *definite priority* in your management thinking. And no factor is more important than maintenance of correct boiler water levels. For water is the *chief source of danger* if not dependably safeguarded. That's why for years Reliance has preached *dual* water level supervision. It's just twice as safe to have both SOUND and SIGHT checks, especially when Reliance Safety Team Equipment is economical insurance against accidents and shut-downs.

The Team is shown here at The Celluloid Corporation, Newark, N. J. Three 610 lb. boilers are protected by sensitive Reliance ALARMs that sound a warning when dangerously low or high water develops. Three EYE-HYE Remote Reading Gages accurately visualize the level at the central control point, eye high like other instruments, so there's no excuse for slighting this important reading.

To make doubly sure that your expensive and important boilers don't suffer from lack of water level supervision, protect them with Reliance Safety Team. Write to Reliance for ALARM and EYE-HYE information.



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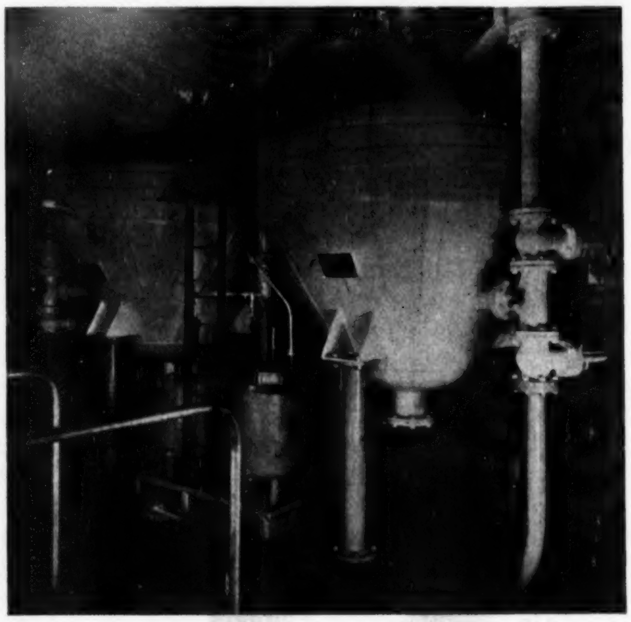
Boiler Safety Devices since 1884

Removing Oil from Condensate

Condensate containing oil or grease if used for boiler feeding is likely to cause serious trouble from foaming and priming, overheating of boiler tubes, or even corrosion. Also, oil carried over with solids in steam to a turbine will congeal and act as a binder for other substances brought over by priming. For these reasons condensed exhaust from reciprocating engines and pumps is usually wasted unless removed by filtration.

Oil that exists in emulsion or a fine state of division must be coagulated prior to removal by filtration and for this purpose aluminum sulphate and caustic soda are widely used. Before entering the filters the condensate is given a treatment of approximately one grain of aluminum sulphate and $^1/_2$ grain of caustic soda per gallon. The resultant aluminum hydrate precipitate forms a flock which coagulates the finely divided oil particles, thus holding the oil on the surface of the filter bed.

In the type of filter here shown the oily condensate enters at the top through an adjustable orifice which causes sufficient resistance to shunt a small proportional amount through the coagulant tank where it becomes saturated with alum and delivers this to the filter side of the orifice at a rate proportional to the flow. The filter bed thus retains the suspended matter at its surface and permits only clear water to pass through and be discharged at the bottom. When the pressure loss through the filter bed becomes excessive, back-washing is necessary.



Courtesy of Cochrane Corp.

Type of oil removal filter used extensively in industrial plants and on shipboard

A simple "rule-of-thumb" test to determine the presence of oil in boiler feedwater is to fill an ordinary test tube to a depth of about two inches with some of the water and shake it well for a short period. If after shaking an accumulation of oil globules appears on the surface of the water one can be sure that there is enough oil present to warrant filtration. If, on the other hand, such globules do not appear it can be concluded that the water is free of oil, or the amount is so small as not to require special attention.

STEAM ENGINEERING ABROAD

As reported in the foreign technical press

Burning Liquid Pitch

In the October 1941 issue of the *Journal of The Institute of Fuel,* E. B. Davies discusses the advances that have been made in the burning of liquid pitch as fuel for steam generation in England. While a number of installations are burning hard pulverized pitch, applications during the past year have dealt with the use of pitch as a liquid fuel.

The pitch, which was formerly largely exported to Continental briquetting markets, has a softening point of around 70 C (158 F), a heating value of 16,250 Btu per lb and contains no inherent moisture. It has a typical ultimate analysis of

Carbon	90	Per Cent
Hydrogen	5.4	" "
Oxygen	2.3	" "
Sulphur	0.7	" "
Nitrogen	1.4	" "
Ash	0.2	" "

The transportation of medium soft pitch in lump form presents no particular problem. During nine months of the year it can be handled the same as screened coal and it is only during particularly warm weather that there is a tendency of the pieces to adhere, but they can readily be separated by a lever. In some cases the pitch is transported in the hot state in insulated tank cars or wagons. A suitably lagged tank with the pitch at 200 C will not lose more than 2 deg F per hr and will thus remain pumpable for at least 24 hr.

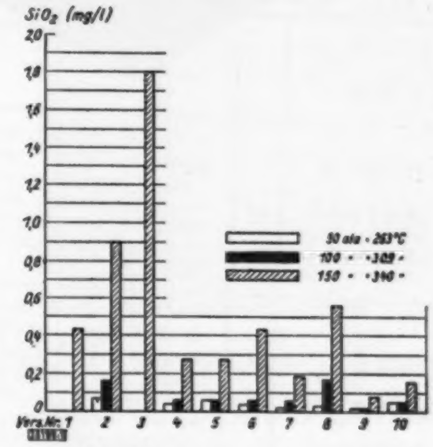
The author discussed the heating of pitch by means of steam coils; by the circulation of hot oil through the melting tank; and by electrical means. The optimum pitch burning temperature is given as 392 F.

For pumping hot liquid pitch either the steam-jacketed ram pump or a motor-driven rotary gear-displacement pump is employed. Atomization of the pitch and its injection into the furnace are generally accomplished by a burner of the high-pressure steam type using at least 50 lb steam pressure. The apparent simplicity of the pitch burner has sometimes led users to make their own, but the author cautions against this practice as it often leads to poor atomization, high steam consumption and carbon deposits in the furnace.

Volatility of Silicic Acid

Silica in the form of silicic acid in water vapor has been believed to cause scaling of turbine blades, but past tests to determine the volatility of silicic acid under such conditions have been unsatisfactory. Reliable results of such determinations at the laboratory of the Technische Hochschule, Stuttgart, are reported by A. Splittgerber in the March 1941 issue of *Archiv für Wärmewirtschaft und Dampfkesselwesen,* which has recently become available. These tests were made with an indicating Pulfrish photometer.

The colloidal silicic acid to be dissolved was made from silicon tetrachloride and the solution mixed with distilled water, which had been freed of carbonic acid, to an SiO_2 content of about 100 mg per liter. Quantities of the solution were then distilled off at pressures of 50, 100 and 150 atmospheres. The results are visualized in the accompanying diagram and show that below 100 atmospheres (1422 lb per sq in.), or below 300 C, without foaming or priming, only small quantities of silicic acid are volatile. But when the pressure and temperature are increased above this there is a relatively large rise in the silicic acid content of the steam compared to that of the boiler water.



1	SiO_2: 25
2	SiO_2: 100
3	SiO_2: 200
4	SiO_2: 100 + NaCl: 3000
5	SiO^2: 100 + Na_2SO_4: 3000
6	SiO_2: 100 + NaCl: 1500 + Na_2SO_4: 1500
7	SiO_2: 100 + P_2O_5: 100
8	SiO_2: 100 + NaOH: 30
9	SiO_2: 100 + NaOH: 12 500
10	SiO_2: 100 + P_2O_5: 100 + NaOH bis

Results of tests showing presence of silicic acid (SiO_2) in the steam

The volatility of silicic acid was found to be materially reduced by the presence of neutral salts, such as NaCl and Na_2SO_4 (tests 4 to 6) and by weak alkaline reactions up to pH values of 11 (tests 7 and 8), under otherwise similar working conditions. A stronger alkalinity apparently further reduces the volatility.

The "Isotherm" Turbo-Compressor

The characteristics of a turbo-compressor differ materially from those of a reciprocating compressor. With the latter, the quantity of air delivered is practically constant for a given speed, regardless of the delivery pressure, and varies proportionately with the speed. How-

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LOW & HIGH TEMPERATURE RESISTANCE	✓	R & I Block provides minimum heat conductivity, hence maximum efficiency, stability, and resistance at temperatures up to 1800° F.
SINGLE LAYER INSULATION	✓	You can safely apply R & I Block directly against any hot surface. No need for combinations of different insulations to effect best possible efficiency; no layers and double labor time.
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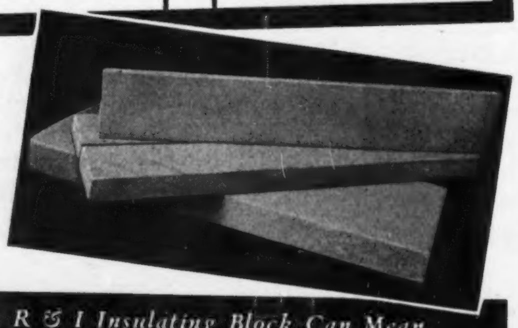

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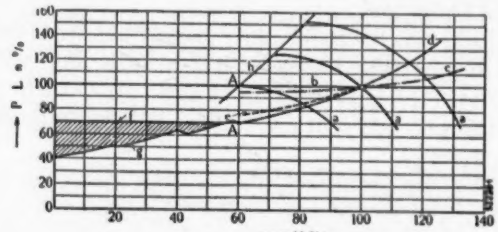
ever, in the case of a turbo-compressor, the volume delivered varies considerably at constant speed with the ratio of compression; that is, with the delivery pressure. To each ratio of compression there corresponds another delivery volume, and as the pressure against which the compressor delivers, rises, the volume drops, and *vice versa.*

When the highest pressure ratio is attained corresponding to a determined minimum delivery volume, the operation of the turbo-compressor tends to become unsteady and intermittent "pumping" results. To prevent this various devices are employed.

When speed regulation is possible, as with turbine drive, it is generally possible to work with loads varying between about 125 per cent and 60 per cent of the rated delivery volume, the rated pressure remaining constant,



— Fundamental characteristics of a turbo-compressor of Brown Boveri design, with back-flow turbine.

V. Volume compressed
P. Pressure ratio } in percentage of rated value.
L. Power input
A. Pumping limit for P = 100 % = constant.

a. Pressure-volume curves for different speeds.
b. Regulation curve at constant delivery pressure = 100 %.
c. Speed curve corresponding to curve b.
d. Power-input curve corresponding to curve b with variable speed according to curve c.
e. Power-input curve with throttling on suction end and constant speed corresponding to normal pressure volume curve a.
f. Power-input curve in pumping range with blow-off valve.
g. Power-input curve in pumping range with back-flow turbine.
//////. Power recuperated in the Brown Boveri back-flow turbine.
h. Pumping limit.

without provoking pumping. On the other hand, with electric drive at constant speed, the loading possibilities free of pumping are between 100 per cent and about 60 per cent.

A simple and widely used remedy to enable the compressor to deliver still lower volumes satisfactorily is to use a blowoff valve. However, as the power input is not thereby reduced but corresponds to the pumping limit, this method is not very economical.

A solution to this problem is provided by Brown Boveri through making the energy contained in the air blown off do useful work in the compressor. To this end the "Isotherm" compressor, described in *The Brown Boveri Review* (Vol. 28, Nos. 4 and 5), is equipped with a back-flow turbine which prevents pumping, the impulse wheel of this turbine being mounted directly on the compressor shaft. The nozzles of this turbine are arranged so that the blowoff air is admitted in sequence according to the requirements within the pumping range. After passing through the turbine the air exhausts at practically atmospheric pressure.

The compressor is equipped with a cooling system which carries out compression along a line that is practically isothermal and delivers air from the final stage at a relatively low temperature; for example, with 60 F cooling water the leaving air temperature is about 102 F.

Engineering Training for Women at Stevens Institute

Announcement has been made by Stevens Institute of Technology, Hoboken, N. J., of a twelve-week basic engineering course open to college women who desire technical positions in war industries. The aim is to equip such women for positions as draftsmen, computors, inspectors and testers.

The course, under the direction of the "War Industries Training School," will cover an eight-hour day, five and one-half days a week. Tuition will be free, but students will have to provide for their expenses. Present facilities limit the number of applicants to 125, in groups of 25 to a section. However, it is anticipated that it will be possible to provide such courses for a greater number of women.

Impulse Blade Research

Facts obtained from recent turbine-blade research by Westinghouse give a new concept of forces on an impulse blade as it moves into and out of a steam jet. The force diagram is not a flat-top curve with gradually rising front and smoothly diminishing tail, as might be expected. Instead, there is a negative peak as the blade enters a steam jet, and a sharp, high force peak as it leaves. The optical tests[1] provide factual evidence of the undesirability of single blades, standing alone. At reduced loads it is desirable to have one steam jet per revolution instead of several spaced jets. Blade shock is thereby limited to once each revolution. Resonant vibration cannot be avoided in partial-admission operation. Some of the blades are in continuous resonance with the once-per-revolution impulse by the steam jet. Wakes in steam-flow beyond the blades react to cause vibration. Resonance of blades with these impulses can be avoided by proper arrangement of blades.

Both crosswise and rotationwise vibrations are present. The former are sometimes smaller and less important, but more complex and difficult to predict. Although crosswise stresses are not yet fully explored, the variations between different constructions and their order of magnitude are known. For each set of steam and load conditions there is a preferred number of blades in a group. This can now be predicted mathematically for a given condition. Damping varies widely with different root shapes. Multiple-fit types of blades show most damping. Sufficient damping can be obtained without artificial dampers for all present turbine requirements.

Specifically, the premises for an ideal steam-turbine mpulse blade design are being gradually revealed from this research. These ideal constructions will be put to the acid test of actual operation in a third rotor for the Schuylkill turbine.

[1] See Combustion, March 1940, p. 28, "Superposed Turbine-Blade Research," by F. T. Hague.

FOR THE TOUGH JOBS

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HEAT INSULATIONS

At the plant of the Otis Steel Company, Cleveland, steel sheets to be annealed are stacked on bases and covered with corrugated steel hoods. Gas furnaces are then swung over the hoods.

In these annealing operations, the bases are subjected to extreme heat and heavy loads. In previous experience, the bases broke down after 50 heats—had to be rebuilt. Since rebuilding with CAREY HI-TEMP and 85% MAGNESIA, the bases are as good as new after 50 heats.

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MORE POWER for DEFENSE

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Each installation is scientifically designed to increase heat transfer by increasing the effective tube area.

Ask for the catalog showing typical installations and details of construction.

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BECO-TURNER BAFFLES

Electric Energy Production

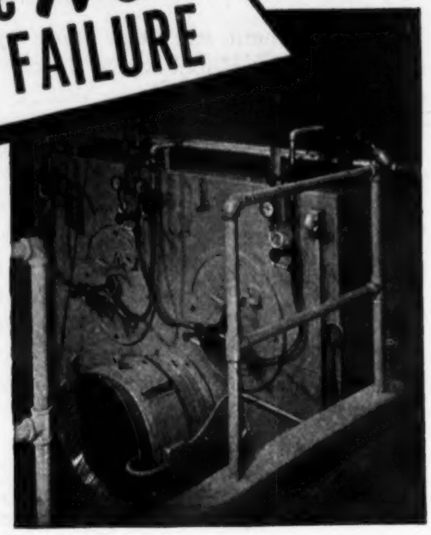
Electric energy produced for public use in November 1941 totaled 14,230,305,000 kw-hr, an increase of 13.7 per cent over that in November 1940, according to a report issued by the Federal Power Commission on December 29. The average daily production of electric energy for public use in November reached an all-time high of 521,256,000 kw-hr, an increase of 1.2 per cent over the average daily production during the previous month. Production by water power was 28.6 per cent of the total.

For the twelve months ended November 30, 1941, the report shows, the total production was 15.5 per cent over that produced in the twelve months ended November 30, 1940.

Net imports from Canada totaled 82,748,000 kw-hr and net exports to Mexico totaled 1,934,000 kw-hr, leaving a net balance of 80,814,000 kw-hr imported into the United States.

The capacity of generating plants in service in the United States on November 30, 1941, totaled 43,788,037 kw, a net increase of 375,331 kw over generating capacity reported in service on October 31, 1941. However, occasionally changes are made in plants which are not reported promptly, so that capacity figures shown for any one month do not necessarily mean that all the changes were made during that month but that they have been reported to the Commission since the issuance of the previous monthly report.

... There must be NO MECHANICAL FAILURE



PRESENT demands require, more than ever, that a boiler STAY "on the line" for long, uninterrupted periods. Where oil fuel is used, this calls for absolute dependability on the part of the oil burning equipment . . . there must be no mechanical failure.

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Handling Coal at Lowest Cost

Hundreds of superintendents and managers of power plants of every size who are storing and reclaiming coal with SAUERMAN Power Scrapers say that this equipment is giving them a maximum of satisfaction.

These machines operate rapidly and economically—handling coal into and out of storage in any required capacities. Coal is piled layer on layer (to 40 ft. heights) and the constant movement of the scraper across the pile packs the coal tightly so that there are no air pockets, hence no chance for spontaneous combustion.

Each unit is operated by automatic controls, and the operator is housed in a comfortable control station.

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SMALL SAUERMAN SCRAPER SOLVES TYPICAL COAL STORAGE PROBLEM

This shows a 3/4 cu. yd. Sauerman Scraper handling coal on a long strip of ground adjoining a power plant. This is a small but very active storage. The minimum duty required of the scraper is to move 160 tons of stored coal per day to the bunkers. On days when coal is arriving for storage, the little scraper may handle as much as 400 tons, both storing and reclaiming.

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Coal Stocks and Consumption

According to figures released on January 5 by the Office of Solid Fuels Coordination, U. S. Department of the Interior, consumer stocks of bituminous coal on hand, as of December 1, represented an average of 43 days' supply for all industries. This estimate was based on the November rate of consumption which totaled 43,054,000 tons. In so far as the electric utilities are concerned, however, their stocks are considerably higher and averaged 67 days. The total estimated production of bituminous coal for 1941, prorated on figures for eleven months, was 499,657,000 tons. This represented an increase of 11.2 per cent over 1940.

The November consumption was distributed as follows:

	Tons	Per cent of total
Electric utilities	5,531,000	12.8
By - product coke ovens	6,848,000	15.9
Beehive coke ovens	835,000	1.9
Steel and rolling mills	912,000	2.1
Coal-gas retorts	143,000	0.3
Cement plants	628,000	1.5
Railroads	8,747,000	20.3
Other industries	10,910,000	25.4
Retail dealers	8,500,000	19.8
Total	43,054,000	

NEW CATALOGS AND BULLETINS

Any of these publications will be sent on request

Automatic Flow Controllers

A new 8-page catalog (section 51-B) has been issued by the Fischer & Porter Company describing its new line of "Rotomatic" air-operated flow controllers for liquids, vapors and gases in piping systems. Adjustable flow control over the entire flow range of the rotometer is claimed, together with 150 per cent throttling range, and automatic reset for synchronizing to process lags and load changes. Installation and wiring diagrams are given and numerous photographic halftones illustrate the component parts of the control equipment.

Cast Steel Valves

A new 56-page catalog (No. 12—Sec. C) for cast steel valves has been issued by The Edward Valve & Mfg. Company. Included are complete design, dimensional and metallurgical descriptions of Edward cast steel stop, check and stop-check valves. Stop valves are both globe and angle, sizes $2^1/_2$ in. to 16 in. for pressures to 2500 lb. Check valves are horizontal, vertical, angle and "Y" in sizes $2^1/_2$ in. to 14 in. for all pressures. Both screw-down and separated types of feed-line stop-checks are shown in sizes $2^1/_2$ in. to 8 in. for pressures to 1500 lb. In the back section, current pressure-temperature adjusted service ratings, flange facing information and drawings, and helpful tips on valve usage have been included.

Chemical Pumps

A well-illustrated 16-page catalog (No. 941) has been published by Milton Roy Pumps describing its expanded line of chemical pumps and proportioners. Pumps with capacities adjustable to one pint per hour are shown, together with pumps adjustable to 2000 gallons per hour. Heavy duty pumps for pressures up to 20,000 lb are also featured, and a new pump made from transparent plastic is also offered. Boiler-water treatment is also described, and a simplified chart is given to aid in the selection of the right pump for a specific duty.

Flow Meters

The Cochrane Corporation catalog "Flow Meters by Cochrane" has grown to a 52-page handbook of instrument application to steam; water; air; gas; and viscous, volatile and corrosive fluid measurement. Space is devoted to the importance of flow records and ten different types of instruments are described, including the new linameter for difficult-to-measure fluids, the ring-balance meter for low-pressure gases, electrical and mechanical weir meters, and liquid level instruments. Special sections are devoted to control applications, dual range recorders, detached instruments, and summation meters. A list of available charts, with tabulated descriptions of each, is also given.

Impulse Steam Traps

The Yarnall-Waring Company has issued a new 16-page bulletin (T-1736) describing its line of "Yarway" impulse steam traps and strainers which are available in sizes from $^1/_2$ in. to 2 in. for line pressures up to 150 lb. and special service impulse traps for pressures up to 1500 lb. This two-color catalog is amply illustrated with sectional drawings and installation views. Price, weight and dimension tables are given and helpful suggestions on the selection, installation and operation of impulse traps are also included.

Index to A.S.T.M. Standards

The American Society for Testing Materials has just issued an Index to A.S.T.M. Standards (including Tentative Standards) which should be invaluable to users of its Book of Standards, and to those who wish to determine the scope of A.S.T.M. specifications, test methods or definitions covering a particular engineering material or subject. This 196-page publication is furnished without charge on written request to A.S.T.M. Headquarters, 260 Broad St., Philadelphia, Pa.

Indicating Instruments

The Meriam Company has issued an 8-page condensed catalog (No. C-10) that describes in compact form the company's line of U-type and well-type manometers, draft gages, flow meters, mercury pressure gages, tank gages and all accessories for measuring pressures, vacuums and flows of liquids and gases. This bulletin is complete with illustrations and descriptions of the equipment, suggestions for use, size ranges, dimensions, weights, list prices, etc.

Priorities Procedure

To those who are not yet familiar with the procedure in obtaining a priority rating of A-10 for purchase orders for plant maintenance and repairs the 4-page folder issued by the Wallace & Tiernan Company, together with two copies of Preference Rating Order No. P-46, recently issued by the OPM, will be invaluable. Compliance with the instructions given in this folder will assist the company in securing materials and expedite delivery of equipment required.

Refractories

The General Refractories Company has issued a 74-page booklet covering, in a condensed form, its complete line of refractory bricks, cements, plastics and castable mixes. Half the book is devoted to useful tables that are essential to refractory users in figuring the number and combinations of brick in firebrick construction. The catalog section discusses the properties of various brick bases and indicates the type of service and temperature range of each particular type of refractory. Illustrations include shop and installation views, and many halftone reproductions of standard shapes of brick and tile, and special products.

Stoker Coal Crushers

The McNally Pittsburgh Mfg. Corporation has issued a new 4-page bulletin (No. 941) that gives the latest information available on its line of stoker coal crushers of all types. A new ratchet takeup permits adjustment of crushing rolls while the crusher is in operation. The bulletin is well illustrated and includes a dimension table and a table of approximate capacities.

Turbine Blowers

The L. J. Wing Mfg. Company has issued a 16-page bulletin (T-98) which illustrates and describes 27 typical turbine-blower installations for forced draft on oil- and stoker-fired boilers, as well as for pulverized coal, gas, wood and hand-fired operations. Details of turbine construction, lubrication, bearings and other features of the turbine-blower assembly are also presented, accompanied by numerous drawings and diagrams.

Water Treatment

"Supplementary Treatment of Boiler Feedwater" is the title of a 12-page bulletin (No. 2420) issued by the Permutit Company which discusses in an informative manner the various ways in which a plant may feed chemicals to further condition the feedwater after external water treatment. Various methods of feeding phosphate, sodium sulphite or sodium sulphate are admirably shown in numerous half-page diagrams.

Zeolite Water Softeners

A 12-page bulletin has just been received from the Graver Tank & Mfg. Company describing its line of zeolite compounds and water softening equipment. The zeolite process and the particular attributes of various zeolites are discussed. Recommendations are given regarding the softening and backwash cycles, brining and rinsing. Several installation views are given and a flow diagram illustrates six methods of water softening.

Extending Hours of Labor

The New York State Department of Labor announces that holders of government contracts and sub-contracts as well as orders carrying high priority ratings, who find their production restricted by the hours-of-labor laws, may seek permission for emergency suspension of these laws by applying to the New York State Employment Service, Albany, N. Y.

Personals

Ely C. Hutchinson has lately joined the Research Construction Company as manager of the Cambridge, Mass., Division.

Basil Manly of the Federal Power Commission has been elected vice chairman for the current year, succeeding Claude L. Draper, who has held the office for the past two years.

J. V. Toner has been elected president of the Boston Edison Company, succeeding the late Frank D. Comerford. He has been associated with that company in various capacities since 1931.

S. C. Dows has been elected president of the Iowa Electric Light & Power Company at Cedar Rapids, Ia. He has been with that company since 1913 and a vice president since 1926.

R. W. Herrick has been made manager of the central station department of General Electric Company in the New England District.

G. J. Nicastro has recently been transferred to the New York District Sales Staff of Combustion Engineering Company. A 1925 Stevens graduate, Mr. Nicastro joined the company in 1934 and has served in various capacities in the Proposition and the Controller's Departments. As president of the New York Chapter of Society of Professional Engineers, and secretary of the Executive Committee of the A.S.M.E. Metropolitan Section, he has a wide acquaintanceship in and around New York.

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